AD-A145 336

(2)

AIR COMMAND
AND
STAFF COLLEGE

STUDENT REPORT

PRACTICAL APPLICATIONS OF MATH AND SCIENCE IN JUNIOR HIGH SCHOOLS

MAJOR LAWRENCE N. HYLAND ACSC 84-1335

"insights into tomorrow"

84 09 5 269

DISCLAIMER

REPORT NUMBER 84-1335

TITLE PRACTICAL APPLICATIONS OF MATH AND SCIENCE IN JUNIOR HIGH SCHOOLS

AUTHOR(S) MAJOR LAWRENCE N. HYLAND, USAF

FACULTY ADVISOR MAJOR JAMES WILSON, ACSC/EDDP

SPONSOR LT COL DAVID C. KRAUS, USAF RS/RSAA

Submitted to the faculty in partial fulfillment of requirements for graduation.

AIR COMMAND AND STAFF COLLEGE

AIR UNIVERSITY

MAXWELL AFB, AL 36112

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 84-1335	2. GOVT ACCESSION NO. AD-A145336	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PRACTICAL APPLICATIONS OF MATH AND SCIENCE IN JUNIOR HIGH SCHOOLS		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Lawrence N. Hyland, Major, USAF , [redacted]		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS ACSC/EDCC, MAXWELL AFB AL 36112		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS ACSC/EDCC , MAXWELL AFB AL 36112		12. REPORT DATE APRIL 1984
		13. NUMBER OF PAGES 64
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

STATEMENT "A"
Approved for public release;
Distribution is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Handbook. This project was generated in response to USAF Recruiting Service request for recruiting materials aimed at the junior high school level. Material exposes target group to the mathematical and scientific skills required of Air Force crewmembers. Designed to foster interest in the Air Force and math/science. This is an interim product, final production accomplished by sponsor—USAF RS/RSAA.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

The Air Force Recruiting Service is facing two major problems in the years ahead. First, due to demographic factors, the number of potential recruits is declining. The Youth Attitude Tracking Study (YATS) published in the fall of 1982 concluded that by the year 2000 there will be approximately 74,000 males with a propensity to enlist in the Air Force. This prediction must be viewed in light of the fact that in 1983 the Air Force goal was to recruit 65,000 males to maintain current force levels. The second problem that the Recruiting Service faces is one of quality. With the increasing complexity of aerospace systems, the recruits who do enter the Air Force must have a sound educational foundation in mathematics and science. This requirement for quality in math and science skills may be in jeopardy for the National Commission on Excellence in Education reported in March 1983 that education in these areas has been declining for the last 20 years and continues to decline. The Recruiting Service, then, must address both areas to accomplish its mission. It must attract recruits in sufficient quantity that possess the quality to perform the duties assigned them. This SPS is intended to help the Air Force Recruiting Service perform its mission of attracting quality recruits.

The final product of this SPS project will be a handbook tailored to both foster interest in the Air Force as a career alternative and assist educators communicate the need for study in mathematics and science. The target group for this product is junior high school students. This group was deemed the most critical for two reasons. First, the propensity for military service must be nurtured at an earlier age. The sooner that the Air Force alternative can be presented, the greater are the chances that potential recruits will become interested. The second reason is equally important, for studies have shown that interest in math and science among males is initially higher in the first years of formal education but gradually declines through highschool. This project is intended to show the practical aspects of mathematics and science and thus reinforce the efforts of educators during the mid-education "slump."

This SPS, as presented, is an interim product. Final production, to include graphics and pictures, will be accomplished by the sponsor--USAF RS/RSAA. In coordination with the ACSC staff (Lt Col Macy) this SPS has been double-spaced rather that single-spaced. This format will aid RSAA in editing and final production. In addition, since this handbook is a unique, one-time-use product, it does not require an annotated text.

ABOUT THE AUTHOR

Major Lawrence N. Hyland is a native of Mobile, Alabama. He graduated from the University of South Alabama in 1969 with a degree in Secondary Education, having additionally completed requirements for a degree in History. In 1978 he earned his Masters Degree in General Counseling from Louisiana Tech University.

Major Hyland was commissioned via Officer Training School in July 1970. After completion of Navigator Training School and Navigator/Bombardier Training in 1971 he was assigned to the Second Bombardment Wing, Barksdale AFB, LA as a B-52G navigator. While assigned to the Second Bomb Wing he flew 62 missions over South East Asia and amassed over 700 hours of combat time. Additionally, he served as an Inflight Evaluator and Wing Target Study Officer. As a Target Study Officer he authored numerous documents to assist the wing navigator training program.

In 1979 he was reassigned to the Second Airborne Command and Control Squadron, Offutt AFB, NE as an Operational Planner aboard the Strategic Air Command's Airborne Command Post—"Looking Glass." In 1980 he moved to SAC Headquarters as a Strategic Nuclear Planner in the Combat Plans Directorate (XO) in direct support of the Joint Strategic Target Planning Staff (JSTPS). While serving in this capacity he contributed to several studies which produced analysis of SAC's capabilities to wage Protracted War and attack Imprecisely Located Targets. These documents were widely distributed throughout the Strategic Air Command and the Department of Defense.

TABLE OF CONTENTS

CONTINUED

INTRODUCTION

By now you should understand the basic functions and procedures used in mathematics. You use Adding, Subtracting, Multiplying and Dividing to get answers to everyday questions. You use math to get the answers you need to work and play. The same is true for the men and women who serve in the United States Air Force. They must have certain mathematical skills to perform their duties both on the ground and in the air. This handbook has been prepared by the Air Force to give you some idea of the mathematical and scientific skills required by the people who keep the sky safe and free. As you read through this text, try to see how the skills used by Air Force people are very similar to the skills you use everday in school. You will find the practical applicaton of mathematics both interesting and fun. Knowing how to use math as a tool will help you in the years ahead.

This handbook contains sections which present the practical applications of mathematics and science. It begins with an introduction to the members of an airplane crew and describes what each must do to perform the job of flying an airplane. The text will illustrate how Rate/Time/Distance problems, graphing techniques and computers are used to do the job. The book will also explore a few natural phenomena such as local and global weather and show how they affect aviators. As you go through this book, work the Exercises and see if you can see how the procedures presented in the text apply to you. You will find that mathematical skills are not hard to grasp, but to be comfortable with math you must first determine what question you are going to answer, find the formulas you need to solve the problem and, finally, accomplish the work in a neat, orderly manner. Math is not hard, but to be sucessful you must accomplish each step in a process in a logical fashion.

The men and women who developed this handbook hope that you will enjoy it. They also hope that it will help you better understand the adventures of mathematics and science. Stay in school, apply yourself to your math and science courses and, most of all, "Good Luck" in the years ahead.

Chapter One

THE PEOPLE THAT FLY

The job of flying an airplane can be a difficult task at times. There's a lot of preparation before the airplane can takeoff, many complex jobs to be done while the airplane is flying and plenty of things to do onee the airplane arrives at its destination. Because of this complexity, most large airplanes have more than one person doing the job. This group of people is known as the crew. Air Force and commercial airlines have crews to share the workload in mission preparation and flying. Each crewmember has been trained in various math and science skills so he can do his job. In addition, each knows something about the other jobs so he can help if things get busy during the flight. Let's look at some of these jobs and how each is important to the mission.

INSERT PHOTO OF CREW PLANNING A MISSION

PILOT

The pilot is responsible for the takeoff and landing of the airplane. He must understand the aerodynamic characteristics of the airplane, the speeds required to takeoff and land, how fast and slow the airplane can safely fly and how it will perform when filled with cargo. In the Air Force, the pilot is in command of the crew. He must assure that the mission is planned properly and that the job is done safely once airborne. All Air Force pilots are officers and have college degrees. A good pilot must be a good crew leader and know all technical aspects of the airplane.

INSERT PHOTO OF PILOT

The pilot is normally the one who completes and signs the paperwork which tells the Federal Aviation Agency (FAA) where the airplane is going during its mission.

COPILOT

The copilot assists the pilot in flying the airplane. He or she must also know about the aerodynamics of the airplane and how to fly it. During mission planning, the copilot works with the navigator and crewchief to plan the route, determine how much fuel is needed and decide where the cargo must be loaded so the airplane will be level and stable once airborne.

PHOTO OF COPILOT, NAVIGATOR, AND CREWCHIEF PLANNING

The copilot, like the navigator and pilot, is an officer in the Air Force and a college graduate. He must understand fuel management, weight and balance formulas and navigation prodecures. After a few years of training, copilots become pilots and are given command of their own crews.

NAVIGATOR

The navigator plans the airplane's route of flight for the mission. He must know how to read aeronautical charts (maps), understand how wind and weather can affect the flight and be able to use the various pieces of gear on the airplane used to determine where the airplane is. Navigators must be able to answer three questions to do their job: (1) Where is the airplane's location? (2) Where does it need to go ? and (3) How does it get there from here ?

INSERT PHOTO OF NAVIGATOR

The navigator has equipment on the airplane to help him answer these question--RADAR, radios, navigation computers and celestial navigation devices. You'll read about some of these pieces of equipment later.

CREWCHIEF

The crewchief has some important jobs on the crew. He makes sure that the cargo is in the right place so that the airplane flys level, helps the copilot by making sure the right amount of fuel is loaded on the airplane and, during the mission, watches the flight instruments to make sure the engines and aircraft systems operate properly.

INSERT 2 PHOTOS OF CREWCHIEF

CREWCHIEF MISSION PLANNING

CREWCHIEF AT HIS STATION IN C-141

Crewchiefs are not officers and they need not be college graduates. They have gone to several technical schools in the Air Force to teach them how to do their jobs.

CONCLUSION

As you can see, the crewmembers are trained in various skills. They need these varied skills to get the airplane to its destination safely. Each member of the crew brings to the airplane slightly different bits of knowledge, but all must work as a team to get the job done.

Chapter Two

GRAPHING TECHNIQUES

The Copilot has many duties on the aircrew. He helps the pilot in flying the airplane, he is usually the person in charge of monitoring the radios and navigation aids to make sure they are set to the correct frequencies and, during the mission planning phase, he is responsible for determining the fuel requirements to accomplish the mission. In this section we will see how the Copilot uses graphs to do his job.

FUEL PLANNING

Constructing the fuel planning log is much like a rate/time/distance problem. The copilot must know the rate at which the airplane burns fuel and compare the fuel available to how long the airplane must fly. His job is complicated because the rate of fuel burn depends on the weight of the airplane. The airplane loses weight as it burns its fuel, so the weight is constantly changing. To make is job easier, the copilot makes a fuel graph.

DATA GATHERING

The copilot begins the task of building the fuel graph by looking in a technical manual which tells him how much fuel the airplane burns relative to its weight. This data was gathered by the people who built the airplane, so they should know. In the following figure you will see an example of the information the copilot gets from this book:

AIRCRAFT WEIGHT (POUNDS)	FUEL BURNED PER HOUR (POUNDS)
260,000	12,000
255,000	11,800
250,000	11,300
245,000	11,000
240,000	10,800
235,000	10,500
230,000	10,200
225,000	10,000
220,000	9,800
215,000	9,500
210,000	9,200
205,000	9,000
200,000	8,800

FUEL FLOW GRAPH

WEIGHT DETERMINATION

The copilot next determines how much the airplane will weigh at the start of the mission. To do this, he adds the weight of the airplane to its cargo; this is called the net weight or basic weight. The basic weight of the aircraft is constant and will not change during the mission. The copilot completes weight computation by adding the basic weight to the fuel weight. The result of this is the gross weight. Gross weight is the total weight the aircraft will carry into the air.

AIRCRAFT WEIGHT + CARGO WEIGHT = BASIC WEIGHT

BASIC WEIGHT + FUEL WEIGHT = GROSS WEIGHT

Below we see the copilot's computations for this mission:

100,000	AIRCRAFT WEIGHT
+ 60,000	CARGO WEIGHT
160,000	BASIC WIEGHT
+100,000	FUEL WEIGHT
260,000	GROSS WEIGHT

After computing the gross weight, the copilot checks his technical manual and finds an expected fuel burn rate of 12,000 lbs. / hour for 260,000 gross weight.

EXERCISE

How much fuel per hour would the airplane use if it weighed 235,000 lbs. ? To find this answer, go back to the Fuel Flow Chart, find 235,000 lbs. in the left column and read the figure across to the right. What did you find ?

FUEL USAGE COMPUTATION

Now that the copilot has computed the gross weight he has a starting place. He begins to gather the information he will need to construct the fuel graph. The fuel graph will provide him with a "picture" to consult during the mission to make sure that everything is going OK. He makes this picture by computing the numbers he needs and graphing them. This is how he does it:

WEIGHTS	REASON	POINT IN THE MISSION
260,000	Gross weight	Takeoff
-12,000	Fuel burned in first hour	Inflight, first hour
248,000	New Gross Weight	Takeoff plus one hour

The copilot finds that one hour after takeoff the airplane should weigh 248,000 lbs. This weight is the takeoff gross weight minus the fuel burned. To determine the fuel burned in the second hour of flight he returns to the Fuel Flow Chart. If there is no weight exactly like the one he is looking for, he goes to the next higher number. This is known as rounding. Rounding will induce a small error in the fuel planning computation. The next hour's answer will show the airplane burning more fuel than it actually will. Even though rounding induces a small error, it is an error in the safe direction. It never hurts to have a little more fuel than you thought you would, especially if you are in an airplane. Next you will see how the copilot determined the fuel flow figures for the second hour of flight.

AIRCRAFT WEIGHT (POUNDS)	FUEL BURNED PER HOUR (POUNDS)
250,000 lbs.	11,300 lbs./hr.
248,000 lbs.	?
245,000 lbs.	11,000 lbs./hr.

FUEL FLOW GRAPH

The copilot sees that 248,000 is not listed in his manual, so he goes to the next higher number (250,000) and uses that fuel flow to continue his mission planning. He continues this process for the entire mission plan to estimate the fuel consumption during the flight.

WEIGHTS	POINT IN THE MISSION
260,000 *	Takeoff
-12,000	
248,000 *	Takeoff + 1 hour
-11,300	
236,700 *	Takeoff + 2 hours
-10,800	
225,900 *	Takeoff + 3 hours
-10,200	
215,700 *	Takeoff + 4 hours
- 9,800	
205,900 *	Takeoff + 5 hours
- 9,200	
196,700 *	Takeoff + 6 hours
- 8,800	
187,900 *	Takeoff + 7 hours

* These are the numbers the copilot will need to construct the fuel graph.

The copilot has estimated that seven hours after takeoff the gross weight of the airplane will be 187,900 lbs. How much fuel is left in the airplane at that point ? To find this he subtracts the weight of the airplane and its cargo (Basic Weight) from the 7 hour Gross Weight of the airplane:

(If) GROSS WEIGHT = BASIC WEIGHT + FUEL WEIGHT
(Then) FUEL WEIGHT = GROSS WEIGHT - BASIC WEIGHT
FUEL WEIGHT = 187,900 lbs. - 160,000 lbs.
FUEL WEIGHT = 27,900 lbs.

MISSION TIME	GROSS WEIGHT	-	BASIC WEIGHT	=	FUEL REMAINING
Takeoff	260,000		160,000		100,000
Takeoff + 1 hr.	248,000				88,000
Takeoff + 2 hrs.	236,700				76,700
Takeoff + 3 hrs.	225,900				65,900
Takeoff + 4 hrs.	215,700				55,700
Takeoff + 5 hrs.	205,900				45,900
Takeoff + 6 hrs.	196,700				36,700
Takeoff + 7 hrs.	187,900				27,900

The copilot found that the airplane has 27,900 lbs. of fuel remaining after seven hours. To get all of the data points he will need to construct the fuel graph he computes the Fuel Remaining figures for the entire mission. The copilot will graph the Gross Weight and Fuel Remaining figures he has computed relative to mission time.

GRAPHING PROCEDURES

There is one important thing to remember any time you are graphing numbers—the scale you use to construct the graph must remain constant. If you start with a scale of two graph squares being equal to one hour, you must continue to do so for the entire graph or it will be confusing to the user.

The following two graphs show how the copilot used the numbers he computed:

INSERT GRAPHS WITHIN TEXT
(see page 59)

In constructing the graphs the copilot had to follow these steps:

1. Decide on a scale which allowed him to get all the weights and times on the chart.

2. Plot the data points (Time versus Weight numbers).

3. Draw a line (slope) to connect the data points.

PRACTICAL USES OF GRAPHS

The copilot will use these graphs to do two very important things:

1. Compare the pre-planned fuel burn data with actual, inflight data.
2. Predict information such as fuel burn rate, fuel remaining and gross weight at various points during the mission.

For example, even though the copilot did not compute the fuel remaining figures for Takeoff plus 3½ hours, he can predict how much fuel will be available at that time. He consults the graph, finds the 3½ hour point on the time line, goes straight up to the slope of the graph (line connecting the data points) and reads straight to the left. He sees that this last, straight line intercepts or crosses the Fuel Remaining axis at 61,000 lbs. He expects to have this much fuel in the airplane 3½ hours after takeoff.

Graphing also allows the copilot to compare pre-planned with actual data. If he reads the fuel gauges at Takeoff plus 4 hours and sees he only has 50,000 lbs. of fuel, something is causing the airplane to run short of fuel. He had expected to have 55,700 lbs. of fuel at that point in the mission. He must tell the crew about this shortage and determine what the problem is—FAST !

EXERCISE

Use the Gross Weight and Fuel Remaing graphs to answer these questions:

1. What is the aircraft's predicted Gross Weight at Takeoff + 5 hrs. ?
2. What is the predicted Fuel Remaining at Takeoff + 4 hrs. 45 mins. ?
3. How long should the aircraft been airborne if the fuel remaining is 40,000 lbs. ?

CONCLUSION

The copilot must be able to use precomputed data to be a good fuel manager. He must use information provided by the aircraft manufacturer to determine fuel consumption.and fuel flow. Once he has determined the fuel flow information, he manipulates this data to compute aircraft Gross Weight and Fuel Remaining figures. Finally, the copilot graphs these data points to construct a fuel graph. He uses the fuel graph as a picture to compare and predict fuel information.

Mission planning for the copilot does not involve complicated mathematical skills, but he must determine before he starts his planning the type of information he will need, how he wants to manipulate and display this information, and what his computed data will be used for.

Chapter Three

RATE/TIME/DISTANCE PROBLEMS

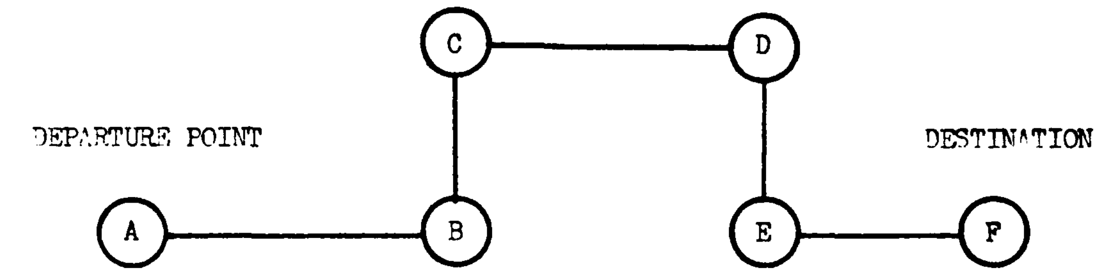
The major job that the navigator has during mission planning is developing the flightplan. The navigator and crew use the flightplan to determine the course the airplane will fly, estimate how long the flight will take and establish an estimated time of arrival (ETA) at the destination. As we have seen, the copilot uses the flightplan to plan fuel requirements and the pilot files the flightplan with the Federal Aviation Agency so that the aircraft can be flight-followed during its mission. In this section we will examine the procedures that the navigator uses in the development of the flightplan.

INSERT PHOTO OF NAVIGATOR MISSION PLANNING

MISSION PLANNING

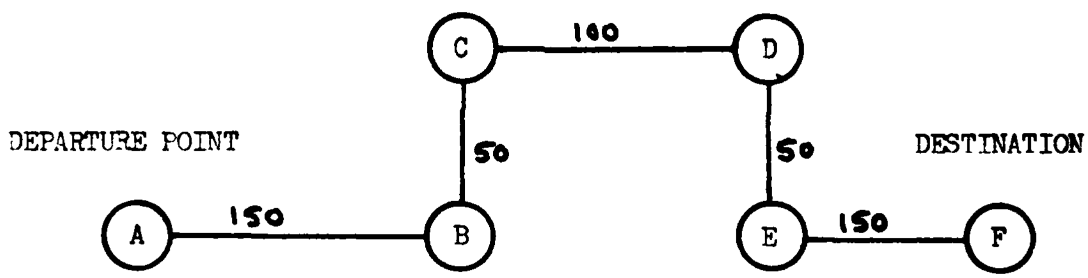
Flightplanning is basically the solution of the Rate/Time/Distance problem. To solve this problem, the navigator uses simple tools (charts, dividers, calculator) and basic mathematical skills. Let's look at how the navigator does his job.

As you already know, the navigator must determine three fundamental things to do his job—the departure point of the mission, the destination and the route connecting these two points. The navigator plots the departure point on his chart, next he plots the destination and, finally, he constructs the route leg segments (course) for the mission.



This process is similar to a Geometry problem. The navigator wants to fly along the route that is defined by a line connecting points A,B,C,D,E,and F. By drawing the route and labeling the points, the navigator has defined the aircraft's intended route of flight.

Next, the navigator uses the chart and dividers to find the distances between each of the points. He writes these distances along each leg of the route once he has measured them.

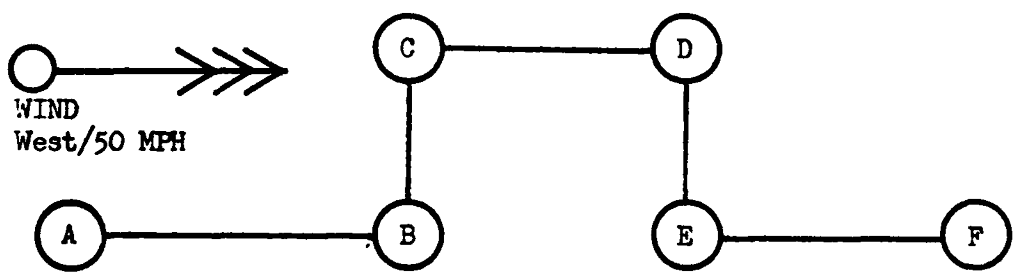


Now he must compute the rate (groundspeed) that the airplane will be flying as it moves along these lines.

GROUNDSPEED DETERMINATION

We need to talk about groundspeed for a minute, for it is important in mission planning. To determine groundspeed, the navigator must know the effect the wind will have on the airplane. Since the airplane travels through the air, any movement of the air will have an impact on the aircraft's speed relative to the ground. The rate at which an aircraft travels across the face of the earth is known as its groundspeed. You will shortly see how an aircraft's groundspeed can vary while the rate through the air remains constant.

To measure the wind's effect on the airplane, the navigator gets a prediction of the wind from the weatherman. The weatherman's forecast tells the navigator from what direction the wind will be coming and how hard it will be blowing (velocity). In this case, the weatherman tells the navigator the wind is expected to come from the West at a velocity of 50 MPH. Below you will see a depiction of how the wind would look if plotted on the chart. What we are looking for is the relationship between the wind and the route. This relationship determines what effect the wind will have on the aircraft and the mission.

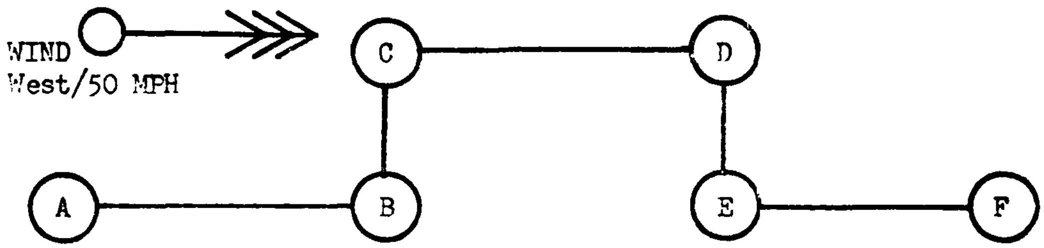


Wind acts on the airplane the same as it does you. If you run outside and the wind is blowing hard on your back, you will run a little faster since the wind is helping you. If you turn around and run into the wind you will move a little slower—the wind is holding you back. If the wind is blowing on your side it has little effect on your speed, but it does feel good to have the wind cool you down while you run.

The navigator must know the airplane's airspeed, the direction and velocity of the wind and intended course to calculate wind effect. Once he knows these, he computes groundspeed using the following formula:

AIRSPEED +/- WIND EFFECT = GROUNDSPEED

The navigator knows that the airplane will be flying at 400 MPH, the wind is predicted to be from the west at 50 MPH and the course. Remember, just like you, if the wind is behind you, you travel faster. If the wind is in your face you travel slower. Knowing this, how fast is the airplane's groundspeed when it flys from point A to point B ?



AIRSPEED +/- WIND EFFECT = GROUNDSPEED
400 MPH + 50 MPH = 450 MPH

How about from point B to point C ?

400 MPH + 0 = 400 MPH

As you see, the wind effect when flying from point B to point C is zero. The wind will be blowing on the airplane's side and will not make its groundspeed faster or slower than its airspeed. The navigator computes the groundspeed for each leg of the mission:

FROM	TO	AIRSPEED +/-	WIND EFFECT	=	GROUNDSPEED
A	B	400	+50		450
B	C		0		400
C	D		+50		450
D	E		0		400
E	F		+50		450

The navigator now knows the groundspeed the airplane is expected to fly on each leg. Since he already has the distance for each leg, he solves the Rate/Time/Distance problem for each leg using this formula:

$$\frac{\text{DISTANCE}}{\text{RATE}} = \text{TIME}$$

The time solution for leg segment A to B looks like this:

$$\frac{150 \text{ miles}}{450 \text{ miles per hour}} = .33 \text{ hrs.} = 20 \text{ minutes}$$

The navigator does this for each leg of the mission

FROM	TO	DISTANCE	GROUNDSPEED	TIME
A	B	150 miles	450 MPH	20.0 minutes
B	C	50	400	7.5
C	D	100	450	13.3
D	E	50	400	7.5
E	F	150	450	20.0
		500		68.3 minutes

Adding up all the leg times, the navigator finds that it will take 68.3 minutes to get from point A to point F. To convert this time to hours he divides his total time by the number of minutes in an hour.

$$\frac{68.3 \text{ minutes}}{60.0 \text{ minutes per hour}} = 1.14 \text{ hours}$$

When the navigator has computed all of his mission planning information he can compute other mathematical data. For example, let's see how the navigator could use his information to determine average groundspeed.

AVERAGING

To compute the average groundspeed for the mission the navigator must use the total distance flown and the total time. The flightplan reflects a total distance of 500 miles and the total time is 68.3 minutes. He will find the average groundspeed by using the following formula:

$$\frac{\text{TOTAL DISTANCE}}{\text{TOTAL TIME}} = \text{AVERAGE GROUNDPEED}$$

Now he takes the information from the flightplan and places it in the formula:

$$\frac{\text{500 Miles}}{\text{68.3 Minutes}} = 7.32 \text{ miles in a } \underline{\text{minute}}$$

As you can see, the answer is in miles per minute. Here is how you find miles per hour if you know miles per minute:

$$7.32 \text{ Miles/Minute X 60 Minutes/Hour} = 439.2 \text{ Miles/Hour}$$

The average groundspeed for the mission is 439.2 MPH, but at no time during the mission is the airplane planned to go 439.2 MPH. Even though this is an average groundspeed, it can be useful to the navigator during mission planning.

PRACTICAL APPLICATION OF AVERAGING

An average is an important tool to be used for comparison. The navigator can compare his average speed over his route to see if there is a faster way of getting to the destination or if another route is possible to take advantage of the predicted winds. That is the advantage of using averages, they allow you to compare one plan with other plans even if the data are different.

You can find examples of averaging in your everyday activity. Suppose you live three miles from school and it takes you 20 minutes to get there. What is your average speed getting to school?

$$\frac{\text{3 Miles}}{\text{20 Minutes}} = .15 \text{ Miles per Minute (Average)}$$

$$.15 \text{ Miles per Minute X 60 Minutes per Hour} = 9 \text{ Miles per Hour}$$

EXERCISE

See if you can solve the following problems, if so, you may make a good pilot or navigator one of these days.

1. Distance = 180 miles; rate = 90 MPH; time = ?
2. Airspeed = 525 MPH; Wind Effect = + 75 MPH; Groundspeed = ?
3. 75 minutes = ? hours
4. What is your average speed if you covered 10 miles in 6 minutes ?

CONCLUSION

As you have seen, mission planning is a relatively simple procedure. The navigator determines distance, computes groundspeed, solves the Rate/Time/Distance problem and adds the leg times to find total flight time. He solves his mission planning problem in the same way you solve mathematical problems; the navigator determines what he wants to find, gathers data from various sources and keeps his work neat and orderly so it doesn't become confusing.

Chapter Four

THE EFFECTS OF WEATHER ON AVIATION

To this point we have looked at some of the mathematical skills required of Air Force crewmembers and the procedures they use to accomplish mission planning. We will now look at the environment the aircraft operates in and a few of the natural events which can affect an aircraft and the people who fly them.

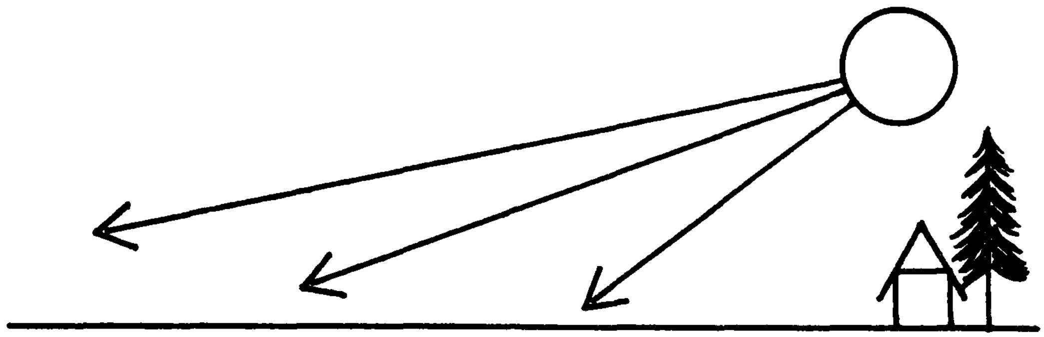
LOCAL WEATHER

Anyone who has ever flown in a airplane has a healthy respect for the weather. Wind, thunderstorms, ice and hurricanes are examples of the phenomena we call weather. Air Force crewmembers must understand weather and how it affects them during flight. Let's see where local weather comes from, how it forms and how it affects airplanes.

COMPONENTS OF LOCAL WEATHER

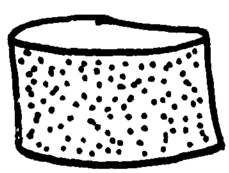
There are many elements that work together to create the weather. The oceans, rivers, deserts and mountains all affect local weather conditions. Even though there are many geographical factors influencing the weather, the two most important elements are heat and moisture. The heat comes from the sun and the moisture primarily from the oceans. Acting together, they generate weather and you can't have weather if either are missing. To prove this, consider our closest celestial neighbor—the moon. There is ample heat on the moon coming from the sun, but there is very little moisture on the moon. You have never seen a thunderstorm on the moon and you never will. The moon has neither the moisture nor the atmosphere to support the formation of local weather.

We'll leave the moon for now and talk about the weather on the earth.



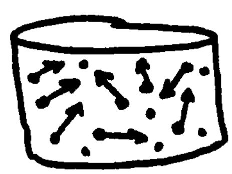
As the sun shines on the earth, it heats up the soil and the air. Things that are warm are more likely to move around than things that are cold. This is true of cold-blooded animals such as lizards and snakes. The sun warms them and they can crawl, climb and slink about more easily. They can move much faster when it is warm. The same is true of the particles that make up our atmosphere. These particles are called air "molecules". When the sun shines on air molecules or they bump into other objects which the sun has warmed, such as the ground or ocean, they begin to move about more quickly. The molecules have become more energetic. Since the molecules are moving faster, they are in one place for a shorter time. Consider this example: you have two gallon jugs, one cold, one hot. At any moment, the cold jug contains more slow, cold molecules than the warm, energetic jug. The cold jug contains a higher density of air molecules than the warm jug.

COLD JUG



Slow moving molecules

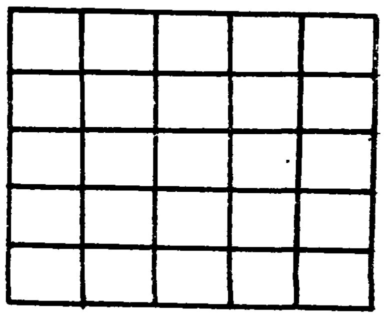
WARM JUG



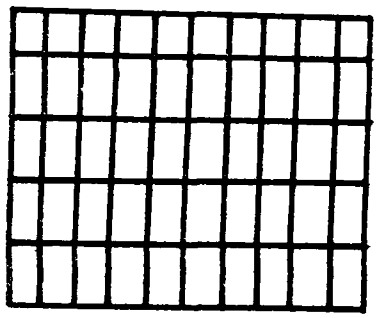
Energetic Molecules

RELATIONSHIP OF DENSITY TO WEIGHT

When we talk about how much material there is in one area compared to how much material there is in another area of the same size we are talking about density. For example, if there are 25 people in your classroom, it has a certain density and there is just so much space between the people in the room. Now imagine that 25 more people come into the room to visit with the first 25 people. Now there are 50 people in the same room. Since the room could not get bigger when the second group came in, the density of people in the room increased and the space between people decreased.



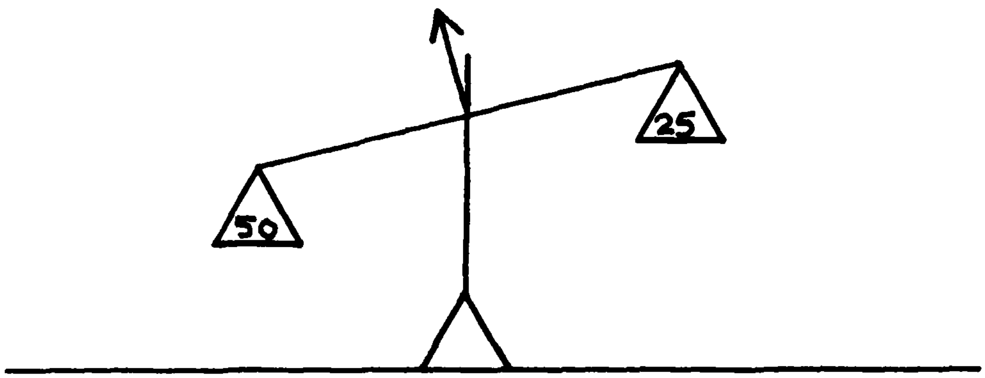
25



50

That's the same thing that happened in the two gallon jugs we described earlier. There are more cold molecules in the cold jug, so it has a higher density than the warm jug.

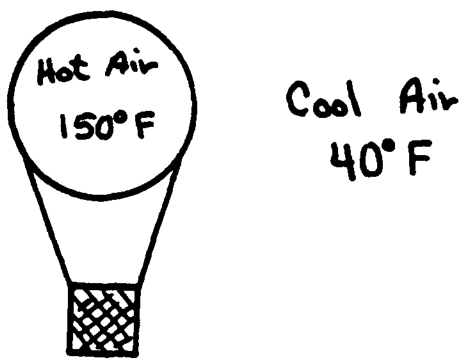
Now that we understand density, let's look at something related to density—weight. Returning to our example of people in the classroom, imagine each person weighs exactly 100 pounds. When there were 25 people in the room, it contained 2,500 pounds. When the 25 extra people came into the room, the density of the population in the room doubled and the weight of the people doubled to 5,000 pounds.



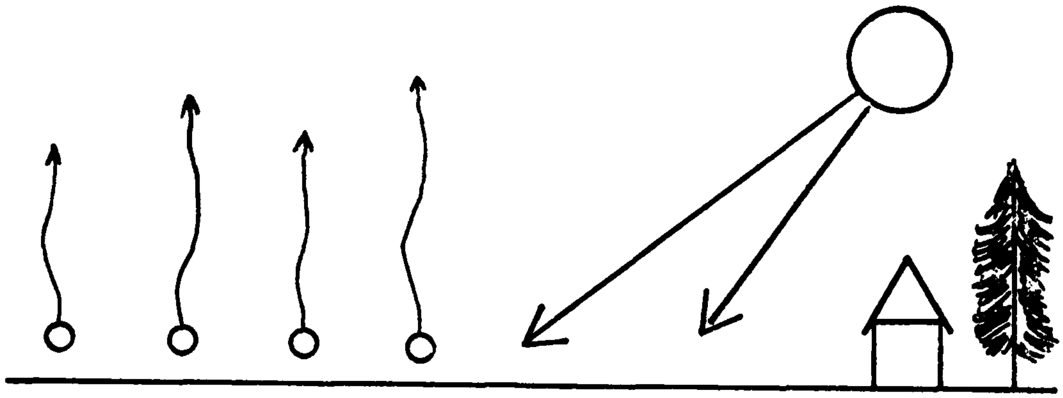
This is the case with our two gallon jugs. Since there are fewer molecules in the warm jug, the combined weight of those air molecules is less than in the cold jug. What does all of this have to do with our weather ? We'll soon see.

RELATIVE DENSITY

You already know that light substances such a styrofoam and most woods float in water. The reason these materials float is called relative density. Wood and styrofoam are less dense than water. A gallon jug full of styrofoam weighs less than a gallon jug full of water. Air molecules perform in the same manner. Warm, energetic, less dense air molecules "float" or rise in cooler air. This is why hot air ballons do the things they do. The ballon pilot uses propane gas to heat air and the big bag above the gondola traps and holds the hot air. The air within the ballon is less dense than the air around it, so the ballon rises.

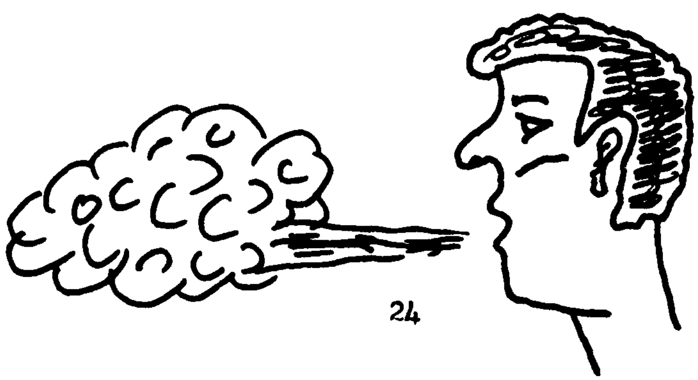


Meanwhile, back to the weather. Remember, the sun has warmed the ground and the ground, in turn, has warmed the air molecules near the surface. Now, this warm, moist air begins to rise through the cooler air above it.



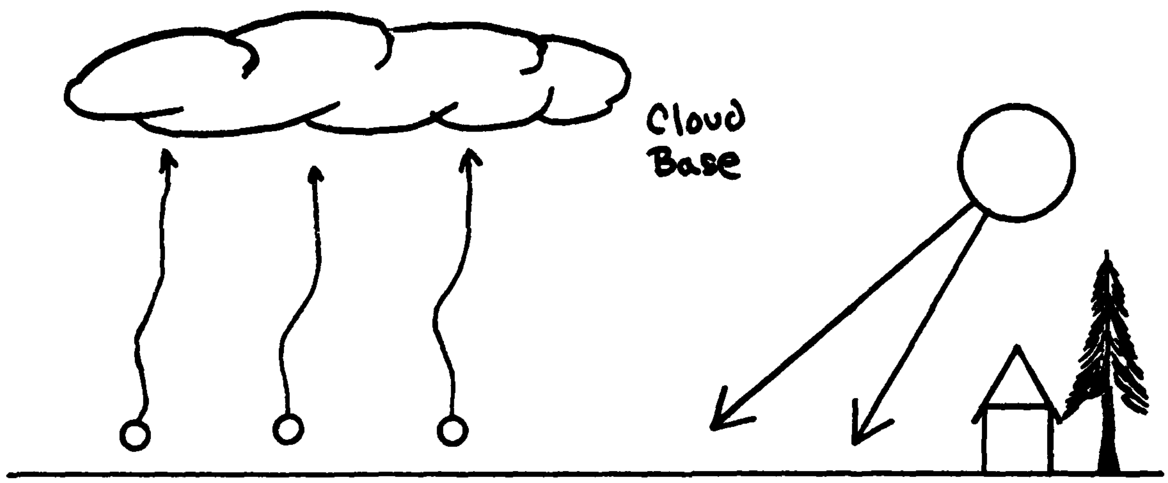
CONDENSATION

As the air rises, things begin to happen. Shortly after the air molecules start their ascent they begin to shed water. This process is known as condensation. Condensation occurs for as the air molecules ascend into the cooler air they cool down. Cool molecules, less energetic than warm molecules, cannot carry as much water vapor with them. You've seen this happen before. The last time you went outside in cool weather and exhaled your breath made a small "cloud". The air in your lungs was heated to 98.6 F by your body so it could hold a certain amount of water vapor. When that warm, moist air met the cold air, it cooled rapidly and could not hold all the water vapor. You generated a condensation cloud when you exhaled. The colder the outside temperature, the greater the relative difference between your lung temperature and the air, so the cloud gets thicker—more water vapor is given up.

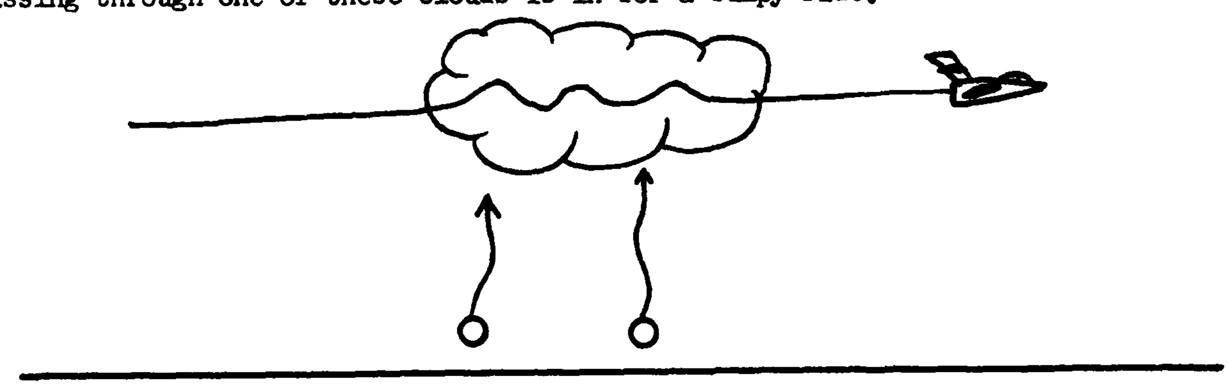


CLOUD FORMATION

Warm air meets cooler air as it rises and, at some point, can't hold all of the water vapor it began its ascent with. At this point, we see clouds form. The "base" or bottom of a cloud is the first point at which we can see warm air releasing water vapor.



The warm air continues to give off water vapor as it rises. If the air does't contain much water vapor when it starts the ascent, clouds may not form or the clouds that do form are small and puffy-white. Weathermen have labeled these small buildups "cumulus" clouds. Cumulus clouds are fair weather clouds, normally seen during calm summer weather. Even though they are generally small, they are evidence of rising air and moisture condensation. An airplane passing through one of these clouds is in for a bumpy ride.

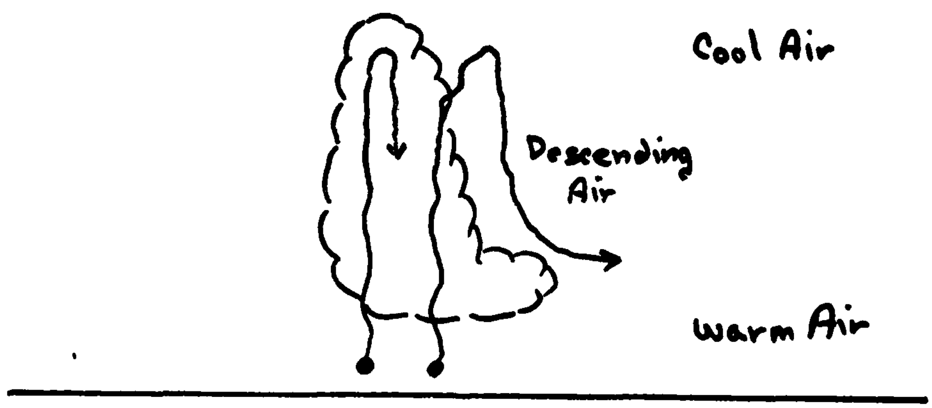


THUNDERSTORM FORMATION

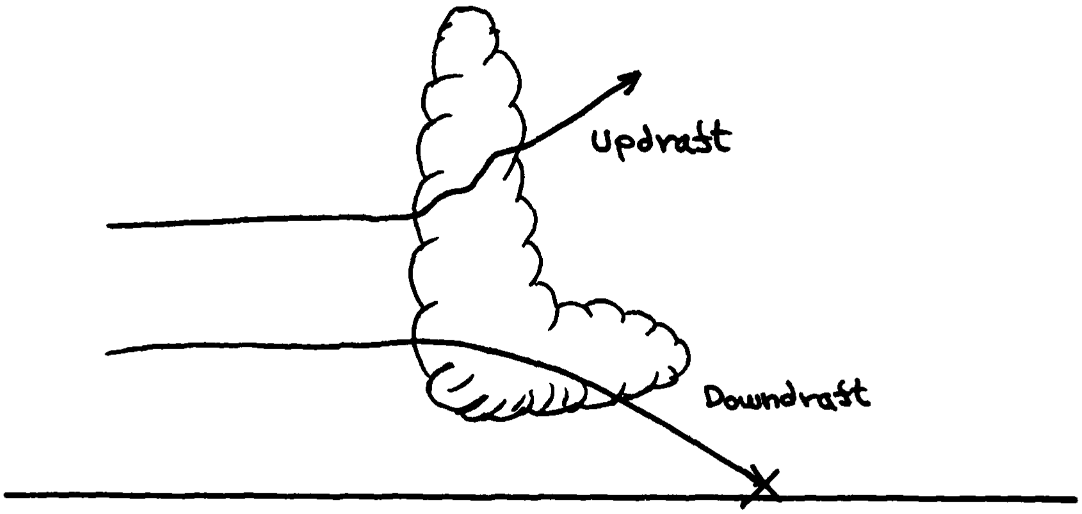
In areas where there is much moisture in the air, over the ocean for example, it takes a long time for the rising air to shed all its water vapor. In this case, clouds tower for thousands of feet. Thunderstorms, on average, can build to 60,000 feet. Some have been seen as high as 80,000 feet. Weathermen refer to thunderstorms as cumulo-nimbus clouds. These clouds are particularly dangerous to airplanes because of their tremendous power. We'll now look at two of these dangers—air currents and lightning.

AIR CURRENTS

The warm air, having risen to the top of the cumulo-nimbus cloud, has shed most of its water vapor and is super-cooled by the air around it. In its cooled state it is more dense and, thus, heavier, than the relatively warmer air around it. You would think that the air would have stopped its ascent when it reached air of the same density, but it didn't. Its previous energy and momentum carried it above air of equal density. Now that it is more dense and heavier than the surrounding air, it begins to fall. This rising and falling of air is one of the most dangerous aspects of thunderstorms.

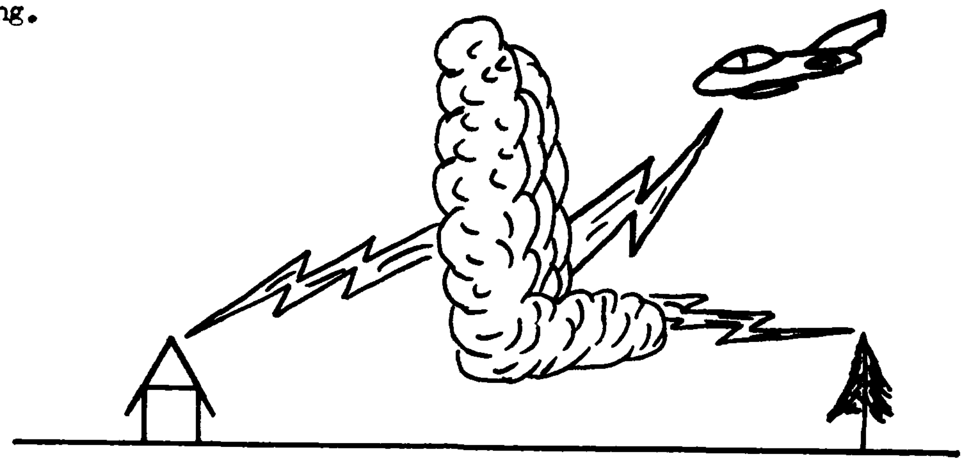


Vertical currents within the thunderstorm travel very fast (about 100 MPH) and can be very close to each other. An airplane flying into these shafts of high velocity air could be torn apart. The nose of the aircraft would be pushed up by one column of air while the tail is being pushed down by another shaft. This is not good for the airplane or the people in it. Slightly less dangerous than these wind current "shears", but still of serious concern to aircrews, are isolated updrafts and downdrafts. An airplane encountering an updraft of downdraft can gain or lose thousands of feet of altitude before breaking free. Downdrafts are very dangerous factors close to the ground for they can drive an airplane into the ground before the pilot can regain control. Knowing this, pilots are wise to avoid flying into thunderstorms. The power of these systems is just too great.



LIGHTNING

The rising and falling of air molecules within thunderstorms produces yet another danger—lightning. Lightning is static electricity generated when air molecules rub against each other in the air currents. People create static electricity all the time. When you comb your hair on a dry day, it gets "frizzy" because the static electricity generated by the comb going through your hair made it stand on end. You also generate static electricity by dragging your feet over a carpet. You generated an electrical charge and it was stored in your body, just like a battery. Then, when you grabbed for a doorknob or another person, you likely saw a small spark and felt a shock. You made lightning. Thunderstorms, because of their huge size, generate and store tremendous amounts of static electricity. If they come near an object of dissimilar electrical charge they release this energy as bolts of lightning. Trees, towers and buildings are the usual targets of these bolts of energy. Lightning is attracted to these high objects for it seeks the shortest path to the ground. If you are in the open when a thunderstorm is approaching, stay away from high objects such as trees and towers. These objects are the most likely to be struck. Lightning can also strike airplanes. Pilots are trained to stay at least 20 miles away from thunderstorms to avoid the dangers of lightning.



CONCLUSION

Now you understand why everyone who flys must understand the factors that create local weather. Although it appears complex, weather is actually composed of simple elements. Heat and moisture are the major components of weather. Heating air reduces its density, causes it to rise and, as a result of rising and cooling, the air sheds its water vapor. As the air cools, it becomes more dense than the air around it, so it falls. The rise and fall of air molecules generates wind shears, updrafts, downdrafts and lightning.

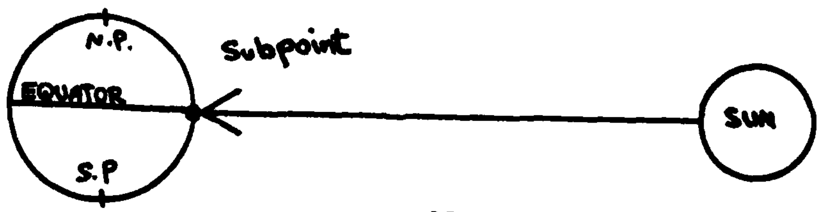
In conclusion, pilots must respect the power and dangers present in thunderstorms. They should never fly through them and it is best to avoid them by at least 20 miles.

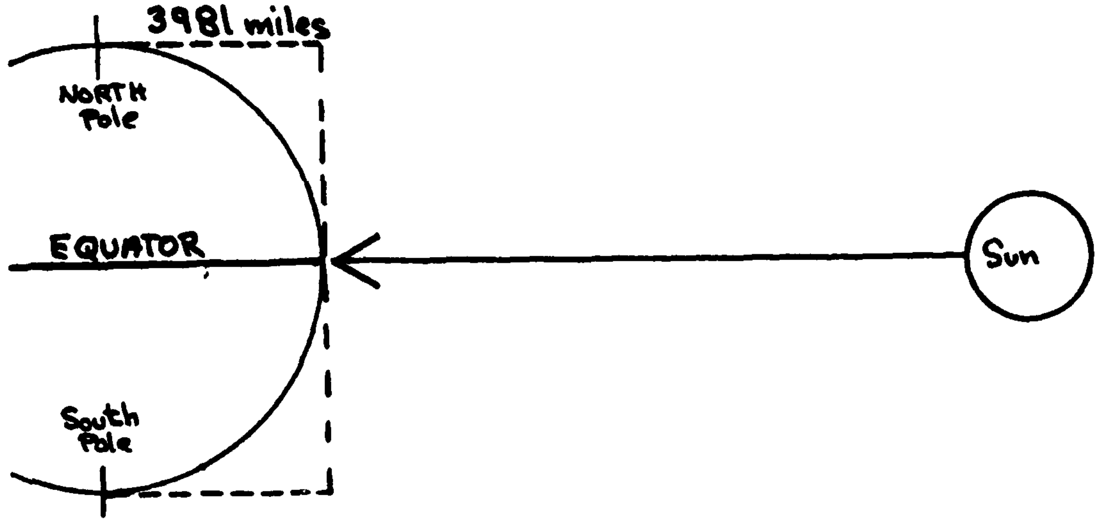
GLOBAL WEATHER

We learned in the last section how the interaction of heat and moisture produces the phenomena we know as local weather. Thunderstorms, rain, lightning and hail are all examples of local weather conditions. We will now look at the elements which create global weather patterns. You will see that the major elements of global weather are still heat and moisture, but bigger factors such as the earth's rotation, differential heating and jetstreams combine to establish the global weather system. In this section we will also see how elements of the global weather system can affect aviation.

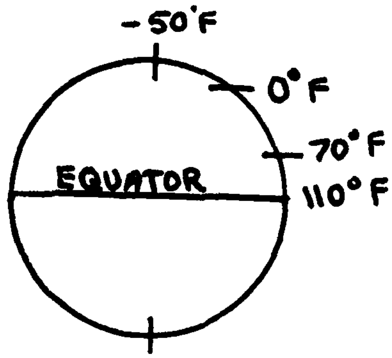
DIFFERENTIAL HEATING

To begin, let's consider the shape of our Earth. As you know, we live on a giant ball or globe. Since the Earth is a globe and not flat, at any moment some part of the Earth is closer to the sun than the other parts. Think about it this way, the equator, that imaginary line running around the middle of the Earth, will always be closer to the sun than the poles. In the following diagram we see the relationship of the sun to the Earth on the two days of the year known as the equinox. On those two days, March 21 and September 23, the subpoint of the sun is directly over the equator. On these two days, the length of day and night are equal, thus the term equinox. Looking at this diagram you see that the equator is, in fact, closer to the sun than the North and South Poles.

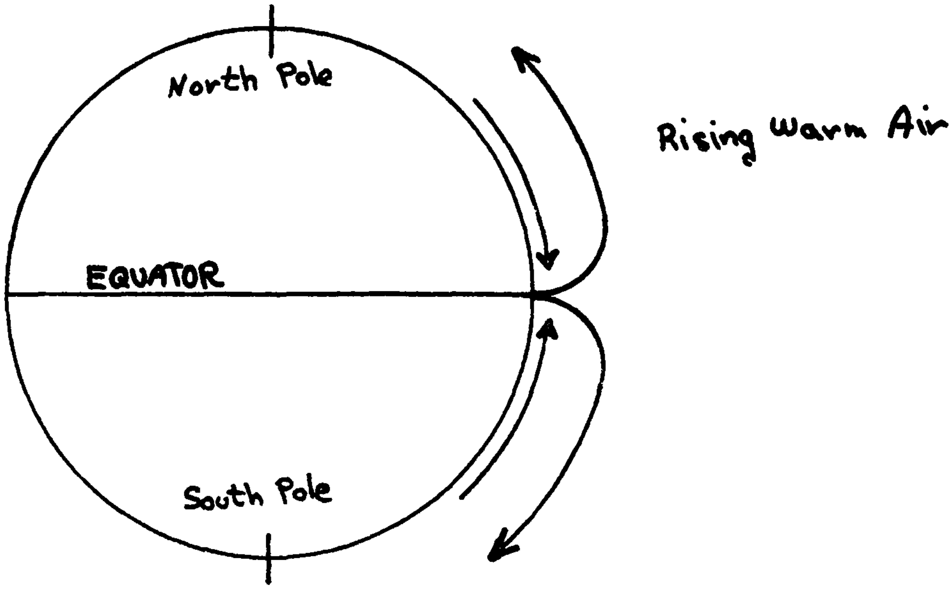




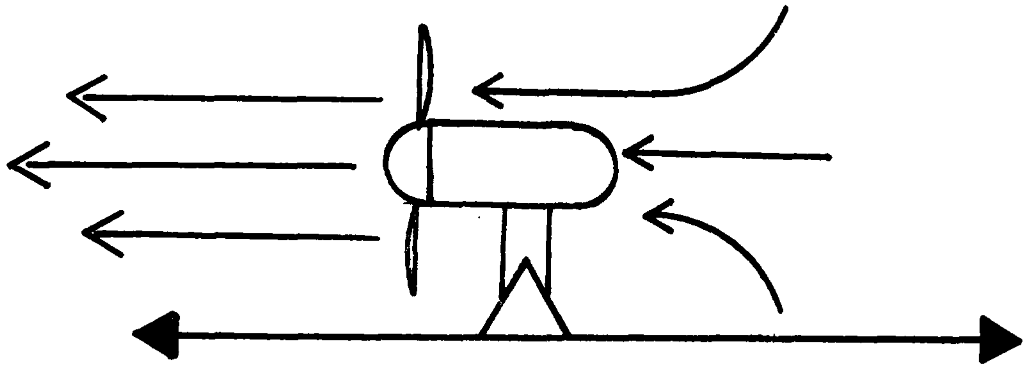
What effect does the fact that certain parts of the Earth are closer to the sun than other parts have on global weather ? The answer is differential heating. Some parts of the Earth are always warmer than other parts. Warm earth heats up the air more than cool earth. As we have seen earlier, warm air is more energetic than cool air. To this next model of the Earth we have added representative temperatures.



Air near the equator is considerably warmer than air near the poles. As a result, warm air at the equator is more energetic. Energetic air tends to rise away from the surface of the Earth.



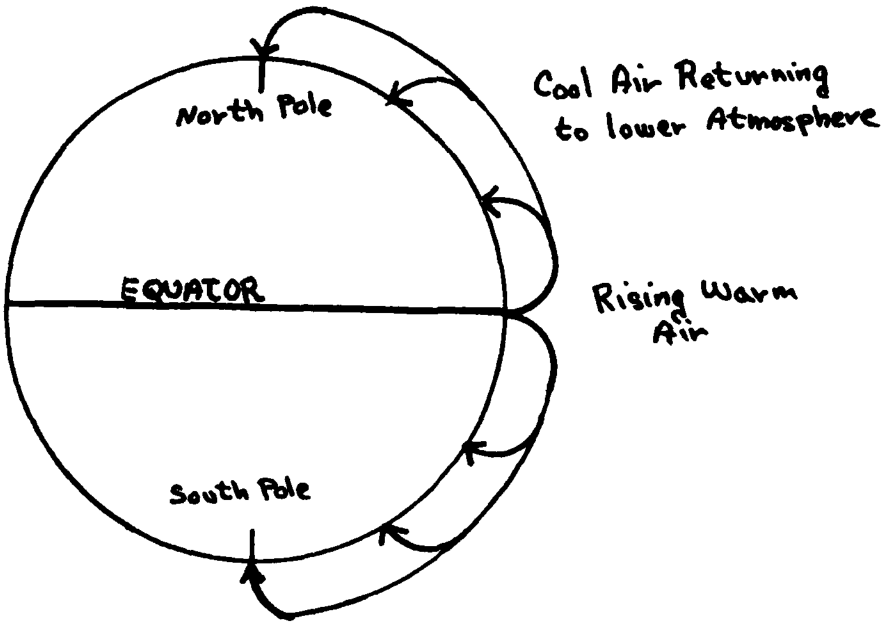
As the warm air rises, cooler air near the surface flows toward the equator to replace it. If the air that moved away from the equator was not replaced, there soon would be no air at the equator. Natural law will not allow this to happen. Nature would like the amount of air to be constant at every point on the earth. Electric fans demonstrate this natural law every day. As a fan blows, air moves in behind the blades to occupy the space .



Place your hand behind the fan and you will feel the air rushing to fill the space in the air the fan has made. Differential heating, then, is like an enormous fan. Air is heated in the equatorial zone of the Earth, this air ascends into the atmosphere and cooler air north and south of the equatorial zone rushes in to fill the void.

ZONES OF DESCENDING AIR

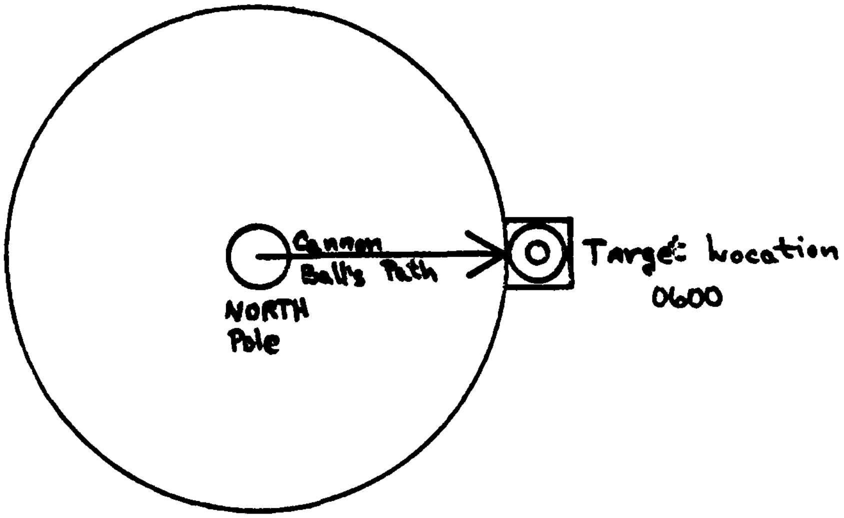
The air that has risen from the equator gradually cools and becomes relatively less energetic than the air over which it is traveling. This air is now cooler, thus more dense than the air below it, so it begins to descend. Cool air descends to earth in three general areas. Some air returns to the earth's surface about 1/3 of the distance between the equator and the poles. Another group of cool air descends about 2/3 of the distance between the equator and the poles. And, finally, some of the air rising from the equator makes it all the way to the poles before it returns to earth.



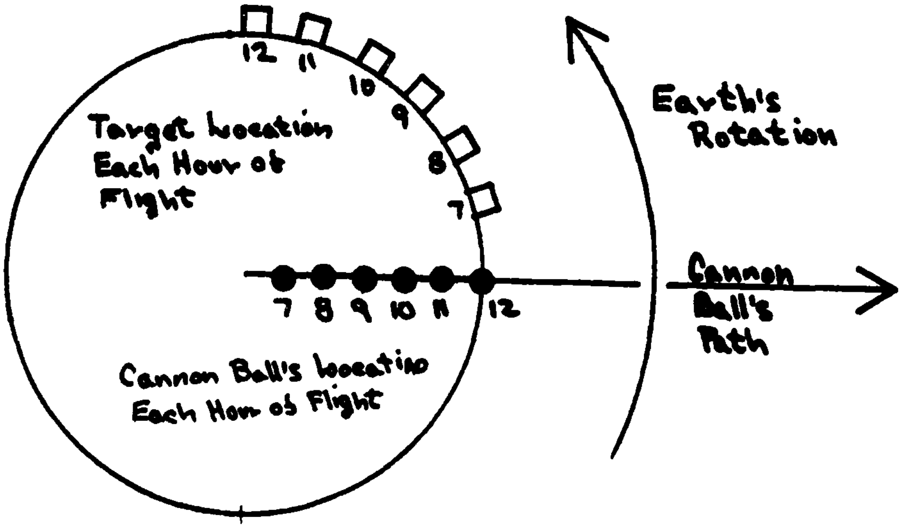
CORIOLIS FORCE

We have seen how air is distributed over the earth's surface as a result of heating and cooling. We must now examine another factor to understand global weather. This factor, the major determinant of global weather, is the earth's rotation.

The earth's rotation around its axis gives rise to a phenomenon known as Coriolis Force. This force exist because as an object passes over the surface of the earth, the earth turns beneath that object. Since the earth is turning and we are standing on the earth, it appears that the object is not traveling a straight path but is moving on a curved path. Imagine you're standing on the north pole, prepared to fire a cannon ball at a target located on the equator. You have a slow cannon ball and the trip from the north pole to the equator will take 6 hours. At 0600 (6 AM) you fire the cannon.



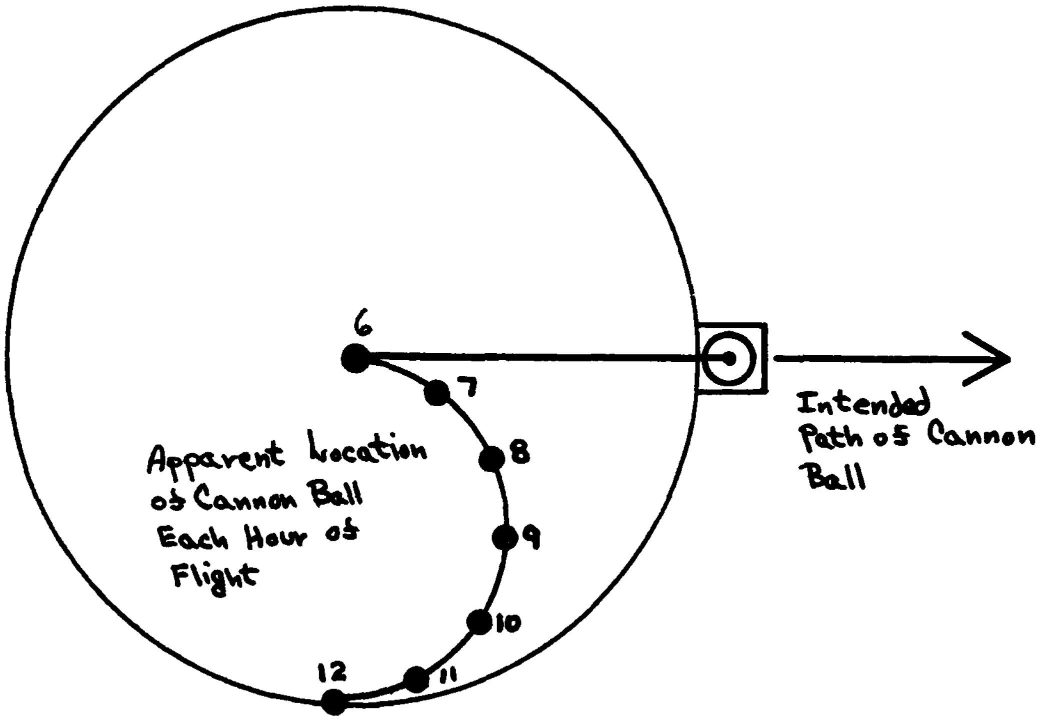
It will take 6 hours for the cannon ball to reach the equator and the cannon ball cannot turn or change course once it is fired. What effect will the earth's rotation have on your ability to hit the target?



As you can see, the target has moved away from the path of the cannon ball.

The cannon ball's impact at 1200 (Noon) will be to the right of the target. Relative to the path of the cannon ball, the target has moved to the left.

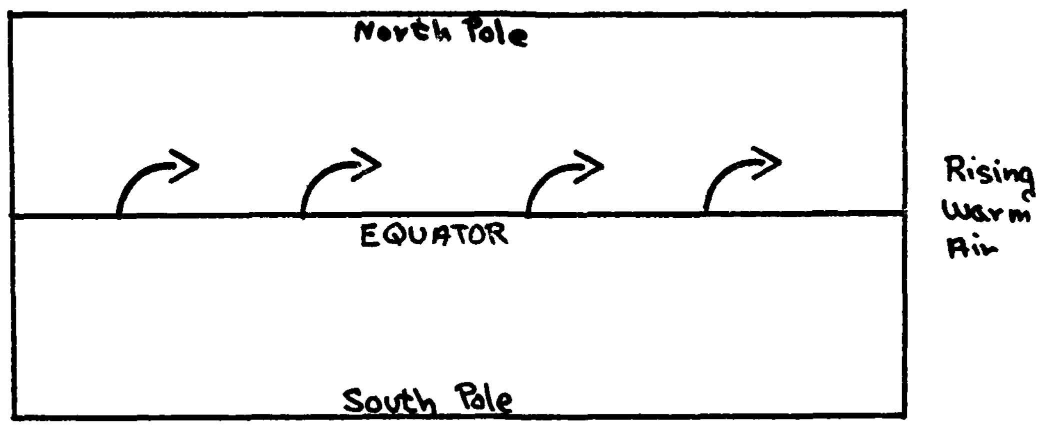
Let's examine this experiment in a different manner and pretend the target remained stationary and the cannon ball moved to the right. This would be the case is the earth did not rotate.



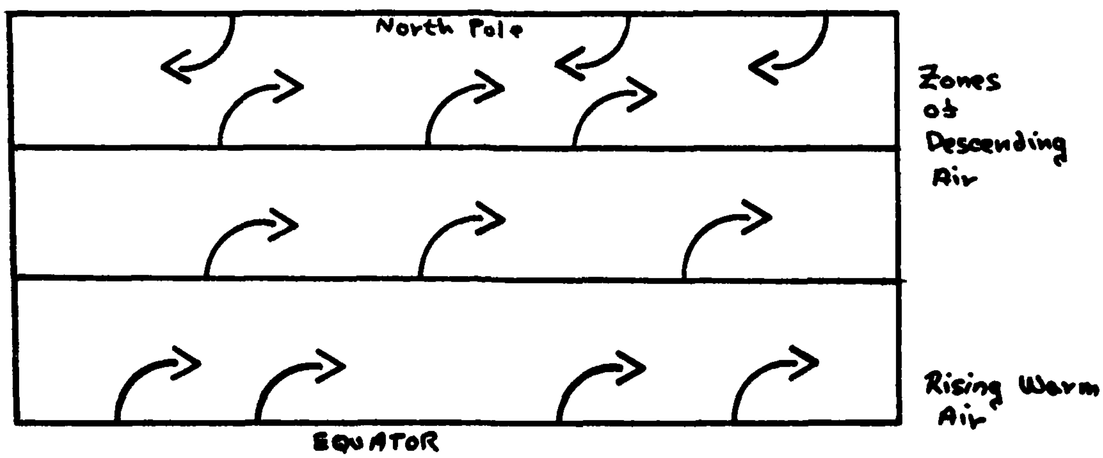
We have displayed the problem in a different manner, from a changed perspective. If the target is not moving, then the reason why the cannon ball missed its mark was the cannon ball's curved path to the right during flight. We know this is not the reason, however. The earth and the target moved and not the cannon ball. This apparent curving of the cannon ball to the right is called Coriolis Force. As a result of Coriolis Force, any object moving over the earth's surface in the northern hemisphere appears to curve to the right. This apparent force is generated by the earth's rotation.

EFFECTS OF CORIOLIS FORCE ON GLOBAL WEATHER

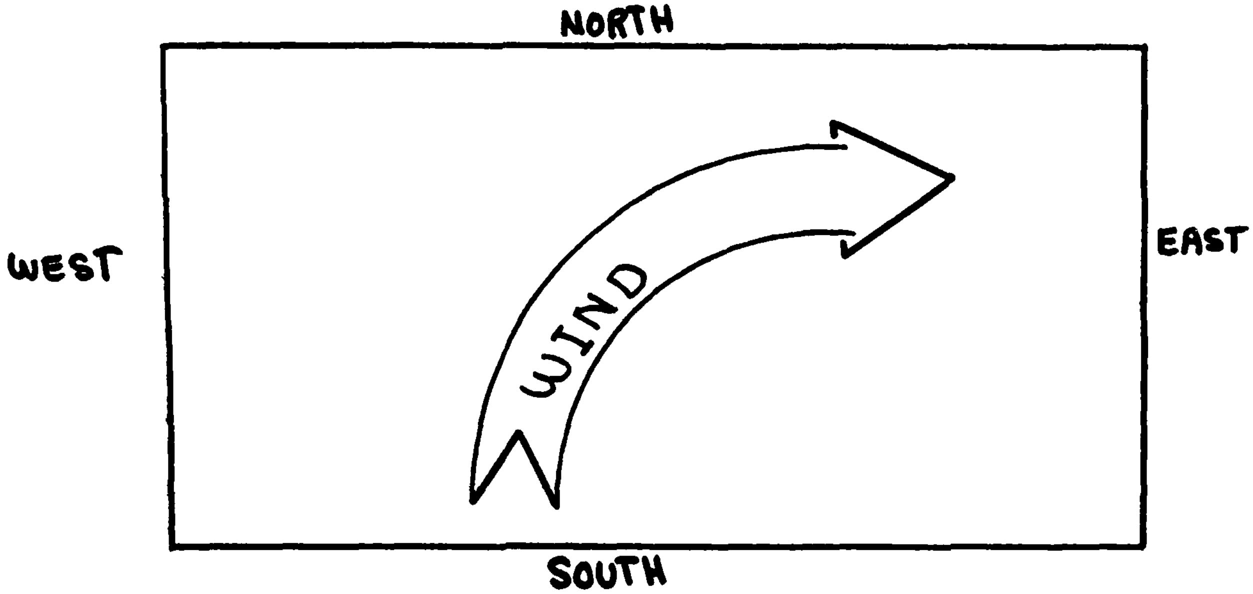
We'll now consider the effect the apparent motion of Coriolis Force has on the air rising at the equator and returning to earth at other points on the globe. To illustrate this point we'll switch from the globe shape of the earth and imagine that the earth is flat.



The first thing you notice on this model is the air moving north from the equator appears to be curving to the right as a result of Coriolis Force.

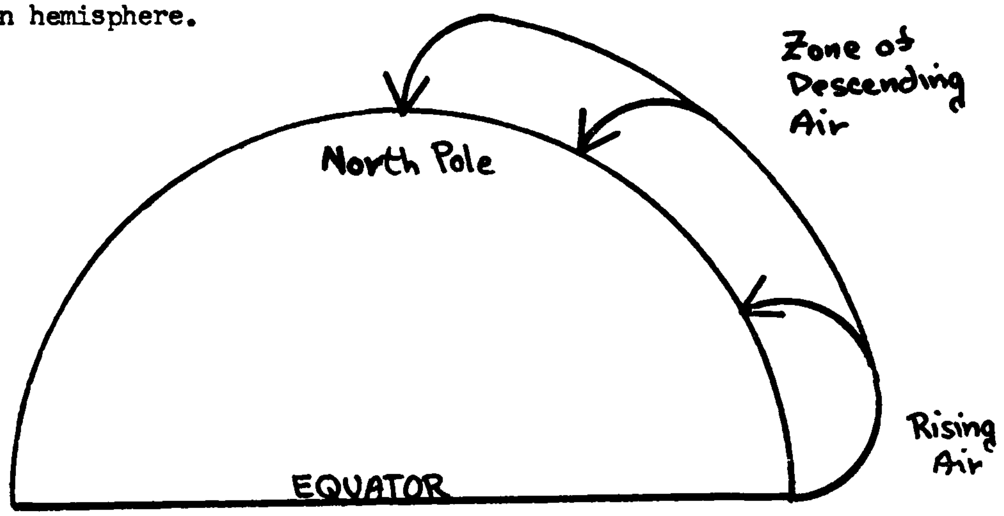


This second diagram shows what happens to the air returning to the earth's surface. It, also, is effected by Coriolis Force and moves to the right. This movement of air results in the flow of air across the surface of the earth. On the northern part of the globe, where we live, this flow of air causes the general wind pattern that we're used to. The wind generally flows from the west to the east. Look at it this way, if the air is moving from the south (the equator) to the north (the poles) and Coriolis Force deflects the air to the right, we on the surface of the earth see this as the wind coming from the west and blowing toward the east.

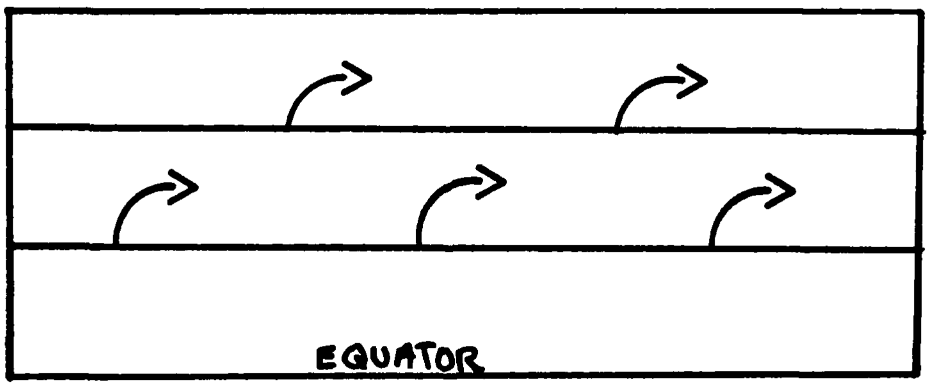


JETSTREAMS

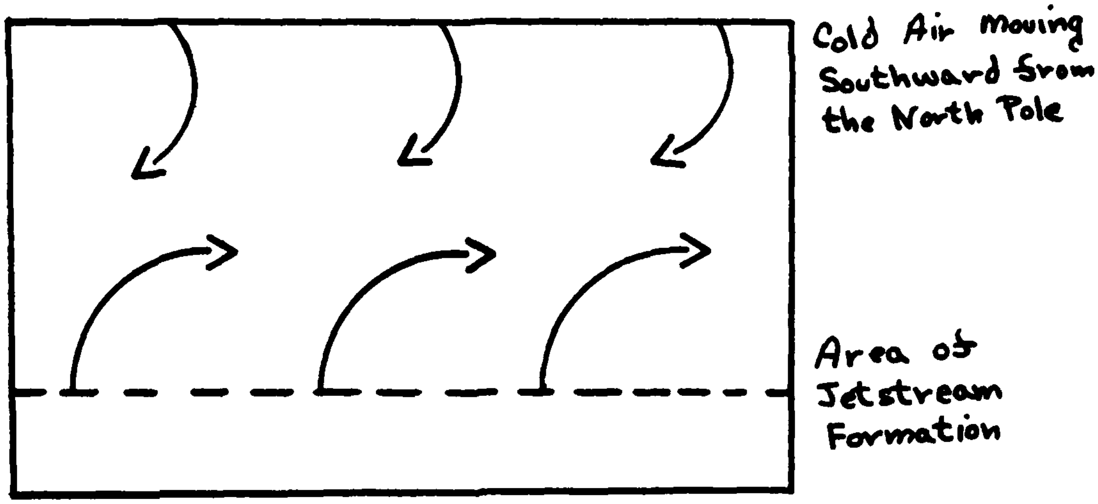
The west to east flow of air across the face of the earth forms yet another phenomenon of global weather--the jetstream. The jetstream is a fast moving current of air, high in the atmosphere, usually about 6 miles above the Earth's surface. You have probably heard the weatherman talk about the jetstream. It is a very important element of the global weather system. The jetstream's location determines if it will be cold this winter, how much rain you will get and how many thunderstorms there will be. To understand the jetstream and how it affects the weather, we need to look at the global wind flow model once again. This time, however, we will look only at the flow in the northern hemisphere.



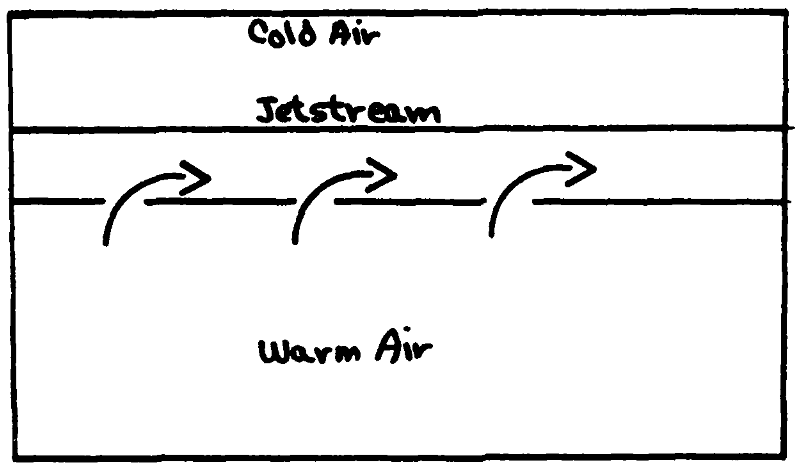
Here we see the air rising at the equator and returning to the surface in general areas along the face of the globe. As the air moves over the globe it is curving to the right due to Coriolis Force. This makes the air or wind blow from the west to the east.



About 2/3 of the way up the globe, the air comes down and moves from west to east. This air is relatively warmer than the air descending to earth at the north pole. This air is closer to the sun than the air at the north pole so it is more energetic. Eventually, the warmer air meets the cool air which is flowing south from the north pole. This meeting of cool air and warm air generates the jetstream. Where these two masses of air meet we have cool, stable air meeting warm, energetic air which is rushing from west to east.



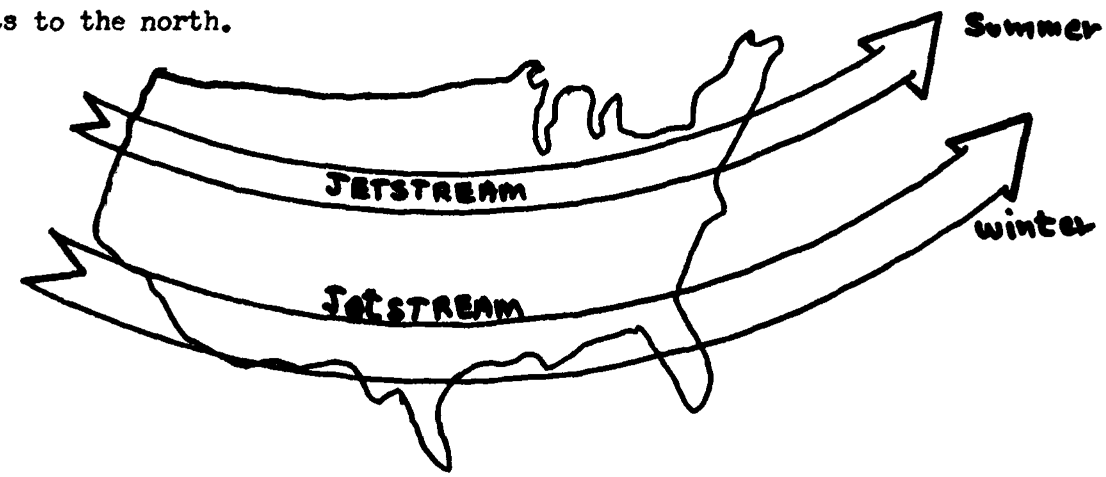
The cool, polar air is pushed from west to east by the warm air and becomes a current or river of air. This river of air is what we call the jetstream.



When you see the weatherman draw the jetstream on his map, remember this—the jetstream is a boundary between cold air from the north and warm air from the south. If the jetstream is north of you, you are in relatively warm air. If the jetstream is south of you, you are in relatively cold air.

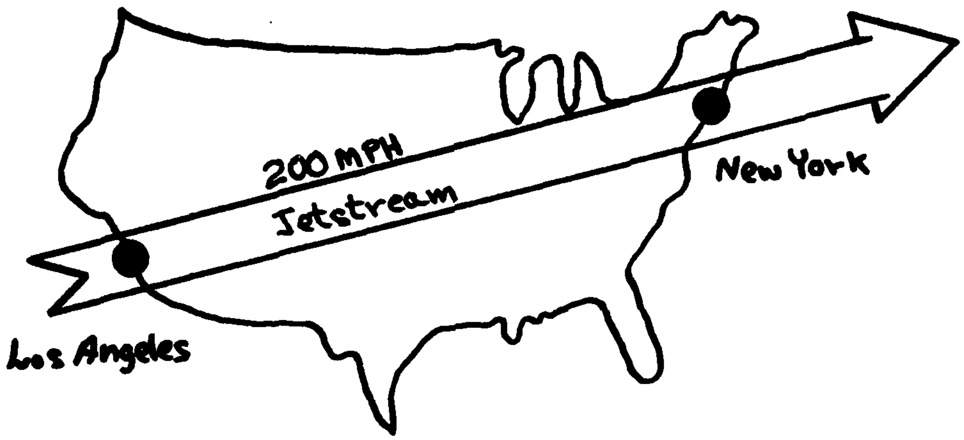
JETSTREAM MIGRATION

The jetstream is not in the same place all the time. It is called a "river of air", but it is a river without any banks. The jetstream migrates north and south during the year, just like the birds, dependent upon the amounts of warm and cold air in the atmosphere. In the winter, the great mass of cold air at the north pole pushes the jetstream to the south. In the summer, when large amounts of hot air move northward from the equator, the jetstream retreats to the north.



EFFECTS OF THE JETSTREAM ON AVIATION

There is one more thing you should know about the jetstream. The winds in the jetstream are very powerful. They usually rush along at about 150 MPH. The jetstream can flow much faster, however, and winds have been recorded as high as 250 MPH. Aviators must be aware of this for the great force of the jetstream can affect their flights. Let's look at an example.



If you must fly from Los Angeles to New York, you would like to find the jetstream for it will help you get to New York faster. It will act as a tail-wind and push you toward your destination. The wind effect of the jetstream will shorten flying time and this saves fuel. This portion of a flightplan illustrates this point.

AIRSPEED	+/-	WIND EFFECT	=	GROUNDSPEED
450 MPH	+	200 MPH	=	650 MPH

As the airplane moves through the air at 450 MPH, the air itself is moving at 200 MPH. In this case, the force of the jetstream is added to the airspeed of the airplane and this greatly increases the groundspeed. Solving a Rate/Time/Distance problem will show you how beneficial the jetstream can be to aviators:

DISTANCE (L.A. to New York) = 3,00 miles
GROUNDSPEED= 650 MPH
TIME = ?

$$\text{TIME} = \frac{\text{DISTANCE}}{\text{RATE}}$$

$$\text{TIME} = \frac{\text{3,000 Miles}}{\text{650 Miles per Hour}}$$

TIME = 4.61 Hours

How long would it take to get from Los Angeles to New York if the pilot did not fly in the jetstream ?

450 MPH + 0 WIND EFFECT = 450 MPH

$$\text{TIME} = \frac{\text{3,000 Miles}}{\text{450 Miles per Hour}}$$

TIME = 6.66 Hours

By comparing the times required at 450 MPH and 650 MPH we find that the pilot can get to New York 2.05 hours faster by flying in the jetstream. Flying in the jetstream saves time and fuel.

Flight Time at 450 MPH	= 6.66 Hours
-Flight Time at 650 MPH	= 4.61 Hours
Difference	= 2.05 Hours

EXERCISE

Consider what will happen to the pilot who has to fly from New York to Los Angeles:

1. Will he want to fly in the jetstream ?
2. What is his groundspeed if he flys in the jetstream ?
3. How long will it take him to get to Los Angeles if he flys in the jetstream ?
4. How much time can he save if he avoids the jetstream ?

CONCLUSION

As you have seen, global weather is a complex interaction of many factors. Rising air, differential heating of the earth's surface and the rotation of the earth work together to establish the patterns of wind flow over the face of the earth. This flow of air cools us, warms us and causes phenomena such as the west to east flow of wind and the jetstream. The jetstream, that fast moving river of air in the upper atmosphere, is a boundary between cold air and warm air. Depending on where it is, we will either be warm or cool. Finally, the jetstream is important to aviators. They can use or avoid the powerful winds of the jetstream to shorten flying time and save fuel.

Chapter Five

NAVIGATION EQUIPMENT

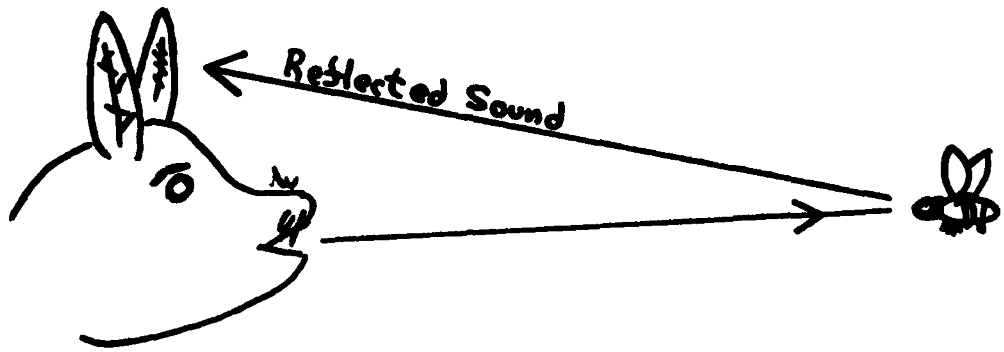
In the final two sections of the handbook we will look at two of the many navigational aids available to Air Force crewmembers. Since we cannot review all of the aids to navigation, we will look at the two that are used the most by the modern Air Force—RADAR and Inertial Navigation Computers. This review should show you how these systems, though electronically complex in many respects, are the result of simple scientific principles.

RADAR

One of the most important instruments the navigator uses during the flight is his radar set. "RADAR" is an acronym, it stands for Radio Detection and Ranging. Radio energy is transmitted through an antenna, this energy is reflected back to the antenna by objects on the ground or in the air and the radar set displays the information on a cathode ray tube (similar to a television set).

THE THEORY OF RADAR

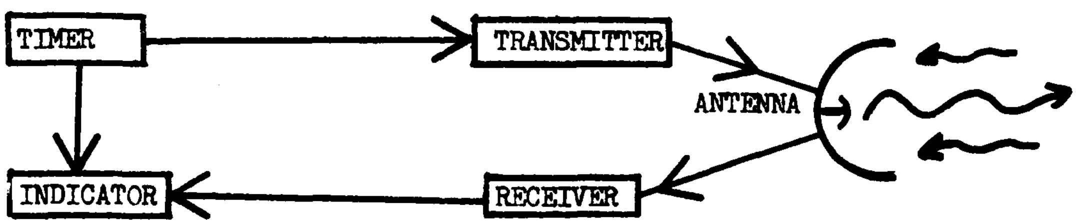
The basic functions of a radar set are similar to the way bats find their food while flying. A bat makes a high-pitched noise and listens. If there is an insect in front of the sound wave, the noise bounces off it and the bat "hears" the insect. The bat can sense the period of time between when it made its noise and the time it returns. It uses this timing information to determine how far it is from the insect.



The bat flys toward the noise reflected by the insect and catches his dinner. The next time you see a picture of a bat, look at its large ears. These large ears act as the bats antenna. Bats feed at night, so radar-like abilities are necessary to help them find their food.

RADAR SUBSYSTEMS

Navigators and pilots use the same process as the bat to tell where they they are, but they don't have to yell and listen intently to get the answer. They use a radar system to get navigation information. They can also use the radar set to locate thunderstorms and avoid them. The following diagram shows the basic components or "subsystems" of a radar set.

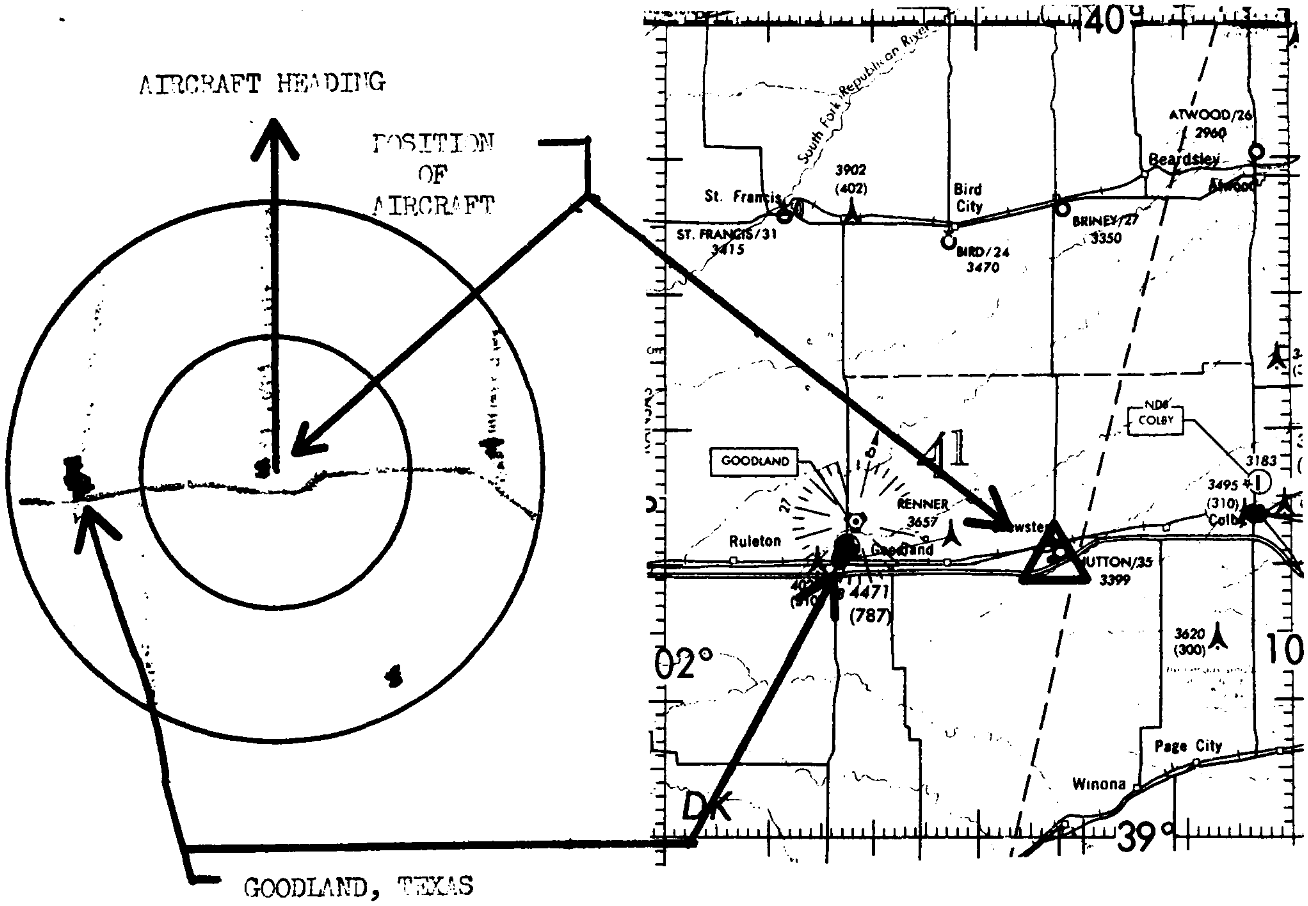


The transmitter functions like the radio transmitter that sends music to your stereo set. The radar transmitter does not send out music, however, just a wave of radio energy at a predetermined frequency. Frequency determination works just like your home radio--if you are listening to the music on channel 1480 you cannot hear the music that is being played on channel 710. The radar set functions in the same manner so it can determine which reflected noise to listen for, otherwise it could not process the reflected information properly.

After the transmitter has generated its wave of energy, it sends it to the antenna. The antenna is normally located in the nose of the aircraft. The radio energy is transmitted in a short "blast", then the transmitter stops transmitting for a short period. While the transmitter is silent, the antenna is listening for the reflected sound. The antenna gathers the reflected energy and sends it to the receiver.

The receiver subsystem of a radar set is exactly like the radio receiver in your home. Your receiver takes the energy from the radio station, amplifies it and routes the music to your speakers. The navigator, however, does not use speakers to display radar information. Radar signals are displayed for the navigator on a cathode ray tube which looks just like a television set.

The cathode ray tube or "indicator" gives the navigator a picture of the objects close to the airplane. This picture is composed of the radar energy which the antenna has gathered. To use this radar picture to navigate he compares the information displayed on his indicator to his chart and checks for relationships. The following graphic shows how the navigator uses the radar information and his chart to find the airplane's location.

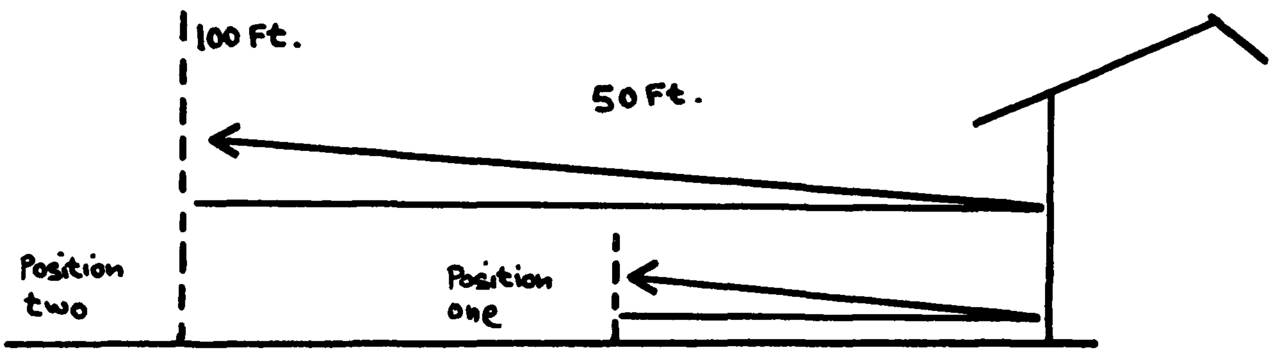


The radar set has shown the navigator where he is in relation to the objects on the ground. He used his chart to find this relationship. Once the navigator has determined his position, he can have the pilot turn the aircraft to get the airplane back on course.

One final element must be added to the radar set so it can function properly—timing. Go back to the diagram of the radar set and look at the timer. The timer is a critical part of the radar set for it is the subsystem which tells the indicator where to display the reflected radio energy coming from the antenna. If all the information from the antenna and receiver were displayed at once, the navigator's indicator would show one big dot. He would not be able to see the relationships between the indicator and the chart. The timer "knows" that the farther an object is from the aircraft, the longer it takes for the reflected radio energy to return to the antenna. The timer, then, displays the pieces of reflected radio energy on the indicator in the same sequence that they came into the antenna and receiver. Here is an experiment you can perform to illustrate the function of the timer.

EXERCISE

Go outside and stand about 50 feet from your house then clap your hands. You will hear a loud "CLAP" from your hands, then you will hear a weak "clap" as the noise returns from the side of your house. Double the distance away from the house and do the same thing. You will still hear two claps, but the time between them will be longer. In the second case, the reflected "clap" will have to travel farther before you can hear it. Let's examine this example mathematically. Before we start, you should know that sound waves travel approximately 1,000 feet per second at sea level.



In position #1 the sound had to travel 100 feet—50 feet to the house and 50 feet back to you. How long did it take ?

$$\frac{100 \text{ feet}}{1{,}000 \text{ feet per second}} = 1/10 \text{ second}$$

In position #2, the sound traveled 200 feet—100 feet to the house and 100 feet back to you. How long did this roundtrip take ?

$$\frac{200 \text{ feet}}{1{,}000 \text{ feet per second}} = 2/10 \text{ second} = 1/5 \text{ second}$$

The distance was twice as far, so the time was twice as long. This shows that there is a relationship between time and distance if speed is constant. There are many applications of this relationship in everyday life.

If velocity (rate) is constant, you can solve the Rate/Time/Distance equation by timing the period between two events. You can tell how far a thunderstorm is from you by counting the seconds between seeing a flash of lightning and hearing the clap of thunder. We'll assume that the speed of sound is constant at 1,000 feet per second. Knowing this, how long does it take for a sound to travel one mile ?

$$\text{TIME} = \frac{\text{DISTANCE}}{\text{RATE}}$$

$$\text{TIME} = \frac{5{,}280 \text{ feet per mile}}{1{,}000 \text{ feet per second}}$$

$$\text{TIME} = 5.28 \text{ seconds per mile}$$

If you start counting seconds when you see the flash of lightning and get to eleven (11) when you hear the thunder you can calculate that the lightning struck approximately two miles from where you are:

$$\text{DISTANCE} = \frac{\text{TIME}}{\text{TIME PER MILE}}$$

$$\text{DISTANCE} = \frac{11.0 \text{ seconds}}{5.28 \text{ seconds per mile}}$$

$$\text{DISTANCE} = 2.08 \text{ miles}$$

If the time decreases between flash and thunder the storm is coming closer.

CONCLUSION

Radar is an important tool used by pilots and navigators. It allows them to determine the position of the aircraft by comparing the information on the indicator with their charts. Although a seemingly complex combination of subsystems, radar is actually a simple scientific concept, akin to the dining habits of bats and the techniques you use to determine how far you are from thunderstorms.

INERTIAL NAVIGATION SYSTEMS

How many times in the last week have you seen or read something about computers ? Computers paint cars, build airplanes, keep records and perform many other functions in today's world. If you want to use computers effectively you must understand a few things about the way they operate, their limitations and their capabilities. In this section we will review some of the terms used when talking about computers, examine the basic computing process and see how computers, namely Inertial Navigation Computers, are used by Air Force crewmembers.

HARDWARE AND SOFTWARE

There are two terms commonly used when talking about computers—hardware and software. You must have both hardware and software to begin the computing process.

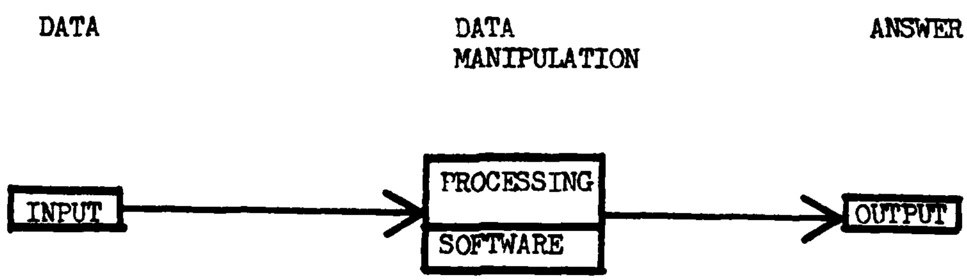
Hardware refers to the mechanical, physical parts of a computer system. The keyboard, television monitor, printer and main frame are examples of hardware. When you think of hardware, think of things that you can carry from place to place. You can see and touch hardware.

Software, on the otherhand, is the mathematical or logical program which directs the computer as it processes information. For example, if you want help in balancing your checkbook, you would purchase a software program (disk or tape) and "load" it into the computer hardware. This software tells the hardware how to process the numbers and facts you type in on the keyboard. Without software a computer will not function. You must have software and hardware to make a complete computing system.

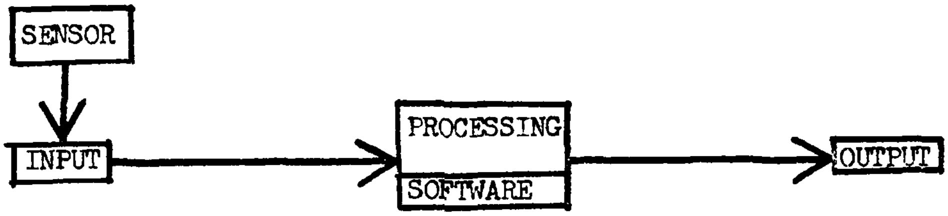
NAVIGATION COMPUTERS

Now that we have seen the basic elements of the computer system (hardware and software), we will now examine the basic computing process and how it relates to navigation computer systems.

There are three steps in the computing process—Input, Data Processing and Output. The computer operator inputs information, the hardware and software process this information and the computer "outputs" an answer. There are many different types of computers, all built to provide different outputs, but the computing process is the same for all. Arcade games, home computers and navigation computers use this same logical process when computing.



The output of a computer can be much more complex and meaningful than the balance of a checking account. This is especially true of Inertial Navigation Computers used in airplanes. These computers are a valuable navigation aid for they help the navigator do his job. Since these computers provide a different output than arcade games or home computers you would expect that the hardware and software would be different. This is true, but the computing process remains the same. Here is a schematic of a navigation computer.

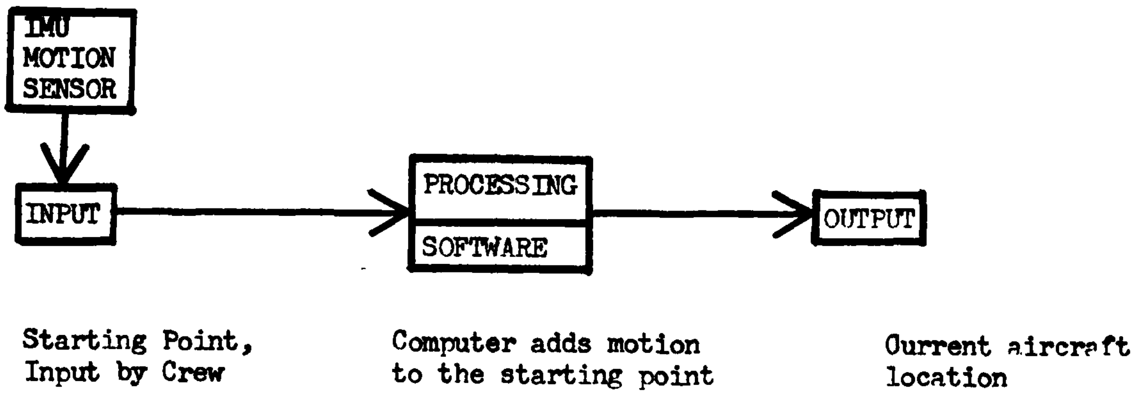


MOTION SENSORS

The model of the navigation computer is similar to the one you have seen before, but one new thing has been added--the sensor. The sensor of a navigation computer is called the Inertial Measurement Unit (IMU). The IMU is a motion sensor and it tells the processing unit how much the airplane has moved since the computer was last given precise location information. Since the output of navigation computers is aircraft location, the computer must be told how much the aircraft has moved. Here is how the navigation computer model works:

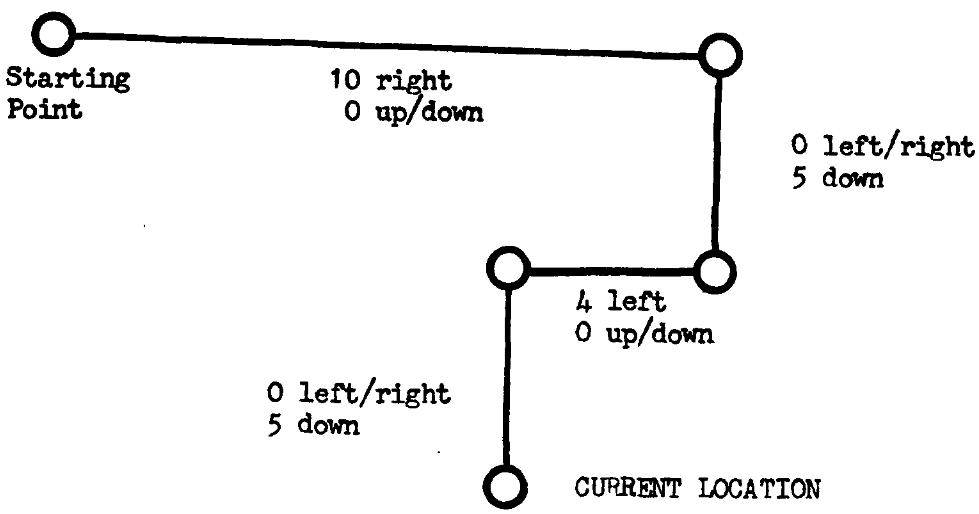
STARTING POINT + MOTION = LOCATION

The navigation computer had to know its starting point when it was told to start computing location. The computer then adds aircraft motion to the starting point and calculates the current location of the airplane.



INERTIAL NAVIGATION

Here is a graphic depiction of what the navigation computer is doing during a mission. In this example, we will assign motion that is up and to the left a plus (+) value. Motion down and to the right will have a minus (-) value.



The computer performed these calculations during the trip:

Starting Point =	0 Left/Right	0 Up/Down	INPUT
	-10	0	
Motion During	0	-5	PROCESSING
Flight	+ 4	0	
	0	-5	
Total Motion	- 6	-10	OUTPUT

By adding and subtracting the motion during the flight, the computer determines that the current position is 6 Right and 10 Down from the starting point. The computer processed the information and gave the navigator an output which reflected the aircraft's present position.

BENEFITS OF COMPUTERS

Now that we have looked at the elements of the computer, the computing process and their application in air navigation it would be beneficial to consider why we need computers. Why are more people using computers everyday ? What advantages to computers offer the user ? The answer to these questions is speed. Computers allow the user to process more data in the same period of time. Banks use computers to keep track of thousands of accounts. Newspapers use computers to process stories, set up the presses and print the papers. Schools use computers to establish class schedules, order food for the cafeteria and keep track of student grades. All of these activities are time consuming if done by hand. Computers allow people to do more and, as a result, be more productive and accurate.

CONCLUSION

Computers are important tools for they allow the user to process more information quickly and accurately. Even though they cannot think for the user they do aid in the grouping and display of information.

The computing process, as we have seen, is quite simple—input is processed by the computer and the output is given to the user. This computing process is accomplished by the hardware which is given the required operating instructions by the software. You will have to work with computers during your life, so it is important that you be familiar with this process so you can use the computer as an effective tool.

CONCLUSION

This handbook should have shown you that mastering mathematics is not a difficult task if you approach each problem in an orderly manner. Before you begin to work, try to sense what the answer should be. Consider the units of measurement you are working with, jot down the formulas you will need to work with and "plug" the numbers into the equation. This logical arrangement of data will help you prevent mistakes and make mathematics easier.

While this handbook was designed to show you how math is an orderly process, it should also show you that there are practical applications of the math skills and science you are learning in school. Math and science are tools and you must learn how to use all the tools available to you to be successful in the modern world. Don't be afraid of math and science, they are the helpers you will need in the years ahead. The more math and science classes you take, the better prepared you will be to meet the challenges of the 21 st Century.

BIBLIOGRAPHY

Books

1. Physical Science Study Committee. Physics. Boston: D.C. Heath and Company, 1966.

2. U.S. Air Force Air Training Command. Air Navigation. Washington: U.S. Government Printing Office, 1973.

3. Van Riper, Joseph E. Man's Physical World. New York: McGraw-Hill Book Company, Inc., 1962

Articles and Periodicals

4. Clayton, Marian "Business Courts the Schools," NEA Today, May, 1983, p. 10.

5. Nash, Robert J. and Ducharme, Edward R. " 'Where There is no Vision, the People Perish': A Nation at Risk," Journal of Teacher Education, Vol. 34, No. 4 (July-August 1983): p. 38.

6. Schuttenberg, Ernest M. "Preparing the Educated Teacher for the 21st Century," Journal of Teacher Education, Vol. 34, No. 4 (July-August 1983): p. 14

7. Steinkamp, Marjorie W. and Maehr, Martin L. "Affect, Ability, and Science Achievement: A Quantitative Synthesis of Correlational Research," Review of Educational Research, Fall 1983, Vol. 53, No. 3, pp. 369- 396.

8. Tyler, Ralph W. "Some thoughts on the Improvement of American Public Education," Educational Technology, August, 1983, p. 7.

9. Wright, Elizabeth E. and Pyatte, Jeff A. "Organized Content Technique (OCT): A Method for Presenting Information in Education and Training," Educational Technology, August, 1983, p. 13.

Official Documents

10. National Commission on Excellence in Education. A Nation at Risk. Washington: U.S.Government Printing Office, April 1983.

11. The Public Sector Research Group. Youth Attitude Tracking Study. Arlington, VA: Defense Manpower Data Center, May 1983.

INDEX

INSERT THESE GRAPHS, AS INDICATED, ON PAGE 10 OF THE TEXT.